SCOLIOSIS



Scoliotic Spine

(From the Department of Pathology Hospital for Joint Diseases New York City)

SCOLIOSIS

PATHOLOGY, ETIOLOGY, AND TREATMENT

By

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Dedicated to the Memory

of

BERTHA RUTH KLEINBERG

WHO E CONSTANT INTEREST IN MY MEDICAL WORK WAS A

STIMULUS TO ME AND AN ENCOURAGEMENT TO MY EFFORTS.

PREFACE

In undertaking a revision of my book on scoliosis published nearly twenty five years ago I found that so many chapters had to be completely rewritten that the present monograph is practically a new book I aim to present the modern concept of the pathogenesis of scoliosis elaborate on our more accurate knowledge of the etiology r view the r sults of the various surgical measures, especially the spine fusion which have been utilized so extensively in many orthopaedic centers but above all to present a clinician s viewpoint so that the orthopaedic surgeon in seeing a case of scoliosis may readily determine its type the prognosis and the most favorable program of therapy

Basically our knowledge of the pathology of scoliosis remains the same and the principles and modalities of therapy are practically unchanged But we have learned a little more about the etiology which has opened up a new and possibly more effective course of therapy For instance experimental work on the spine has proven that the structure and conformation of a vertebra may be influenced by the application of unilateral pressure to the epiphyseal plates (Bisgard) a well established fact in relation to other bones This procedure has already been used in children and it is not beyond imagination hope and probability that in the future such an operation may become extensively applicable with excellent results Actual removal of a congenital extra centrum has been practiced but so far the attendant shock and hemorrhage have deterred us from continuing such surgery This operation which has a sound basis may in the future be perfected to a degree that it will become routine and actually cure some or many cases of congenital scoliosis

A very great step forward in the management of scoliosis has been made in the last two decades through the cooperation of educators throughout the world, who have learned enough about the characteristics and potential progress of scoliosis to collaborate with physicians and health agencies by approving and enforcing periodic physical examination of school children This has been of the greatest value since many scolioses have been discovered in the early or mild stages and have been subjected to vigorous and prolonged treatment with the result that further increase in the deformity was either completely arrested, or the deformity was prevented from reaching a severe degree Certainly fewer cases of advanced kyphoscoliosis and 'razor backs are seen today than were encountered twenty five years ago This I believe to be the direct result of an expanded educational program which encompasses the inclusion in the undergraduate medical curriculum of the major subjects of orthopaedic surgery, the

based on factual information which, although including a knowledge of our current therapeutic limitations, may yet be a stimulus to the interested student to explore through his imagination and by trial and error discover more fruitful therapeutic avenues.

I wish to express my gratitude to the many students of scoliosis from whose experience I have profited. I have consulted many authors to whom I give collectively my thanks. I am very appreciative of the sympathetic and splendid assistance of Mrs. Natalie Friedheim who read the manuscript and made many excellent changes. I wish to thank Miss Ruth C. Lea of my office staff, for her enthusiastic and able assistance in the production of many of the photographs. I am grateful to Dr. Richard Fenton for the drawings illustrating the steps in a spine fusion. Lastly, I sincerely appreciate the interest and cooperation of Mr. Robert S. Gill, President of The Williams & Wilkins Company, publishers of this volume.

establishment in urban centers and even rural districts of routine periodic physical examination of all school children, and the education of parents and teachers in health problems and in the specific advantages of prophylaxis and early therapy

Formerly heredity was assumed to play a minor role in scoliosis Careful study has revealed that nearly 25 per cent of the cases are inherited Moreover my own observations lead me to conclude that an hereditary scoliosis is likely to be of the same character and degree as that of the progenitors This raises a problem in genetics meriting attention While I do not favor and have not the least inclination to remove enchantment and romance from marriage yet I believe that it is our duty to inform a woman or man with scoliosis about to be married that one or more of her or his children may have scoliosis It may at least serve to prevent a scoliotic individual from marrying another with scoliosis in which event the likelihood of scoliosis in the offspring would be very great. The least advantage of such information would be that the scoliotic parent would carefully observe her children and should one of them show scoliosis the condition would surely be recognized in an early stage.

The therapy of scoliosis is more time-consuming than that of almost any other orthopaedic condition It is always a matter of years not infrequently 5 to 10 years of treatment and observation. It requires endurance on the part of the patient and her or his parents, and infinite patience as well as extraordinary labor on the part of the surgeon The surgeon who undertakes to treat a case of scoliosis must therefore have not only the requisite knowledge but also the proper temperament for its management Not only does the surgeon have to expend a tremendous amount of energy in the application of the treatment but he must also possess a great sympathy for the individual with scoliosis to effectively minister to her various needs It is not enough to treat the deformity one must primarily treat the patient and sometimes the family too.

It is planned to give a practical review of the entire subject but not an exhaustive or encyclopedic survey of all its phases Very little for example, will be said about mensuration because the author does not believe that an involved method of graphic recording of a scoliotic deformity has any real practical value A favorable therapeutic change must be grossly evident or it is not of any consequence Similarly there will be little comment on the almost innumerable apparatus and the many Zander machines constructed for stretching the trunk only a few simple ones will be described those commonly and readily available

In the ensuing pages I shall draw chiefly on my widened experience especially as it relates to the etiology and to the principles and modalities of treatment both conservative and operative I hope to establish a viewpoint

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Anatomy, Pathology, Etiology

Cura est magnum opus orthopaediae

Chapter I

INTRODUCTION

Scoliosis is a complex deformity which has occupied the attention of physicians ever since Hippocrates coined the term to describe a deformed spine Its treatment was originally empiric and consisted of measures that seemed to reduce the deformity These measures crude and violent though they were, nevertheless depended upon therapeutic principles which still constitute essential features of modern treatment, namely the elimination of the force of gravity, the use of traction as the basic corrective force and the application of pressure over the convexity of the curve

From the fifteenth to the eighteenth century when careful anatomic studies began to be carried out the pathology of scoliosis became clearer Some progress in diagnosis was made and the term "scoliosis originally used in a generic sense and applied to any type of curved or diseased spine was now limited to the deformity as it is known at present This differentiation from other spinal conditions, especially Pott s disease marked a great advance

In treatment there was no great change until the eighteenth century when fixation of the back in an improved position was combined with corrective forces. Great efforts were made for the forcible correction of the deformity and numerous appliances were devised and tried out At about the same time gymnastic exercises came into vogue and have remained an important aid in therapy ever since

The etiology of scoliosis has received much attention during the last century and while considerable progress has been made much greater knowledge is needed to clarify and completely elucidate the exact pathogenesis and mechanics of the scoliotic deformity

The search for more effective therapy has been continued and the present systems or methods of treatment are much more effective and satisfactory than the older procedures In particular, the deformity is being recognized at an earlier age sometimes at its very inception so that treatment has often arrested a scoliosis at a mild or moderate stage and prevented its progress to a severe degree with its attendant functional disturbances Certain it is that very few cases of the so-called severe or razor back deformity are now seen whereas it used to be common in the past

Scoliosis as a physical deformity is accompanied by functional changes in the thoracic and abdominal organs and psychic and emotional disturbances. The extent of the functional changes in the heart lungs and

tally alert, was about to marry. Before marrying, however, she wanted assurance that she would be able to bear children. Her anxiety on this score allayed, the objections of her prospective parents-in-law had to be overcome.

An 8-year-old girl with a transitional scoliosis strenuously objected to wearing a simple supporting corset. She feared the possible ridicule of her classmates.

The management of scoliosis thus demands of the physician not only a knowledge of the physical and functional changes but an intimate acquaintance with the social status of the patient, the home environment, the financial stability of the family, and last but not least, the patient's emotional reaction to his deformity. Successful treatment depends upon a careful evaluation of all the factors and the adaptation of the plan of therapy to these factors.

Up to about fifty years ago the treatment of scoliosis was exclusively conservative. Surgery was first introduced for cosmetic purposes, and gradually was extended until it is now being utilized for curative purposes. While it has not yet been fully successful, there is every reason to believe that with modern advances in the use of antibiotics, blood replacement, improved anesthesia, and better and safer technics, surgery may be able actually to cure structural scoliosis.

In the following pages I plan to discuss scoliosis from a broad point of view, give the high spots of the views of others and their influence on the evolution of modern thought and methods, but always with an eye to the practical and useful. I shall outline a program of treatment which has proved successful in my hands, laying a basis for the reader and student to make further improvements and progress. Much that time has proved to be fanfare and impractical is omitted. Omitted, too, are some details, such as those of record and mensuration, which in the light of experience have proved of little significance or value. This I do consciously, choosing to concern myself with the essential and basic facts which must dominate intelligent and effective control of a complex and very difficult medical task and problem. I count imagination as the most important element in all medical progress. But it is most fruitful when controlled by basic principles and especially by proved facts.

other viscera is in direct proportion to the degree of physical deformity In the mild and moderate scolioses the functional disturbances are few and negligible In the severe deformities there may be many and marked changes in the visceral functions, and life itself may be threatened. In point of fact, statistics show that very few patients with severe scoliosis survive beyond the fifth decade. A review of 625 cases made some time ago showed that only 2.5 per cent of the patients were more than 40 years old This fact has spurred orthopaedic surgeons to emphasize the imperative need for recognizing scoliosis in its early stage so that it may be prevented from progressing to a severe degree

The psychic factor in scoliosis is a feature that has required serious consideration at all times. The emotional impact of a physical deformity may gravely affect the development of an individual s personality Patients with a spinal curvature are well aware of their physical distortion Some it is true are calm phlegmatic, accept restrictions resignedly and are content to utilize modifications in their clothing to conceal the asymmetry of their bodies. In this group may be found those who conquer their physical deficiency by devoting themselves to and becoming expert in some intellectual pursuit. Literature art, and science have been enriched by the accomplishments of such individuals. They have sought and obtained compensation in intellectual attainments to their own satisfaction and for the benefit of humanity which forever remains indebted to them.

But there are others who yield to a sense of inferiority and defeatism. They become painfully sensitive and introspective more or less jealous of normal persons, and deeply resentful of their unhappy fate Some among them seek superiority and control by any means, fair or foul and make life for all about them an unhappy and discordant affair This group is fortunately a small one But few indeed are they who do not suffer to some degree from the restrictions, physical or social which their deformity imposes on them. It is the barriers they encounter or fear to encounter which cause the greatest anguish and sense of defeat Everyone can cite examples of this attitude To pick a few from among my patients

A young woman with a severe curvature of the spine is so ashamed of her appearance that she avoids any social contact except with those who know her intimately

A 27 year-old man with a marked curvature of the spine and shortened stature isolates himself from all social contacts.

A 19-year-old boy with a marked scoliosis was teased so unmercifully by his school mates that he began to hate them all He spent all his free time at home reading or studying losing what benefit he might have gained from outdoor play and exercise Eventually the wall he built up around himself completely shut him away from the every-day world

A young woman with a moderate scoliosis but otherwise active strong and men

Spine

Consisting, on the average, of thirty three bony segments or vertebrae the spine (Fig. 3) is situated in the midline of the back. In infancy it forms an unbroken backward curve. This curve gradually alters during the first and second years of life as a result of sitting and standing into four curves: in the cervical and lumbar regions the spine curves forward while in the dorsal and sacrococcygeal regions the original backward curve remains.

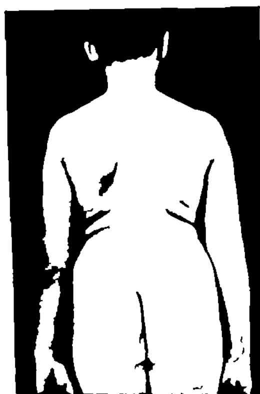


Fig. 1

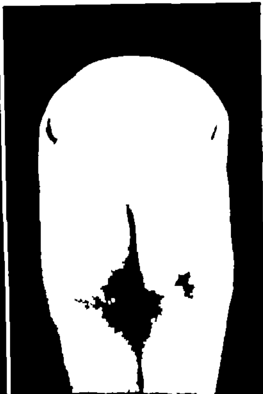


Fig. 2

Fig. 1. Normal back, upright position, spine in midline, symmetric sides.
Fig. 2. Normal back, forward bent position, sides symmetric.

During adolescence the vertebral segments of infancy change into a flexible mobile presacral (or better suprasacral) part consisting of the cervical, dorsal and lumbar vertebrae and into a rigid or immobile part made up of the sacrum and coccyx. The former results from the fusion of the sacral vertebrae, the latter from the fusion of the coccygeal segments.

Morris, *Human Anatomy* (71) describes the spine as follows:

> Viewed ventrally the vertebral column presents a series of pyramids due to the successive increase and decrease in width of the bodies. These become broader from the axis to the first thoracic vertebra and then decrease to the fourth thoracic. The first pyramid therefore includes all the cervical vertebrae except the Atlas, and has the apex directed craniad and its base caudad, whereas the second is inverted and

Chapter II

ANATOMY, EMBRYOLOGY, PHYSIOLOGY

Scoliosis is known by a variety of names, among them curvature of the spine, lateral curvature of the spine and rotary lateral curvature of the spine. The last is the most accurate name indicating, as it does that the spine has undergone a lateral displacement and a twist or rotation. Nevertheless, the term "scoliosis" is preferable, being brief, simple, and universally used.

The deformity of the trunk in scoliosis involves all the bones, muscles, ligaments, and fascia of the back, abdomen, and thorax the spinal cord the thoracic and abdominal viscera and, occasionally the pelvis. The most conspicuous feature is a lateral displacement of the spine and a distortion of the ribs but all the other tissues are also more or less affected. The physical change in the spine is a fairly good index of the morphologic disturbance in the other tissues, so that scoliosis is customarily described in terms of the manifest changes in the spine One must always bear in mind, however that the spinal curvature is only one element in the deformity the greater the curvature the greater the effect on the position, structure and function of all the soft tissues of the trunk, including the viscera blood vessels and spinal cord.

Anatomy of the Trunk

A thorough knowledge of the salient points in the anatomy of the trunk is essential to a clear understanding of the pathology symptomatology and treatment of scoliosis. In the following pages I shall quote liberally from the standard texts on anatomy

Back

The back comprises the posterior parts of the thorax and abdomen and extends from the base of the neck to the buttocks. It contains the spine, the posterior segments of the ribs, and many muscles ligaments, blood vessels, nerves, and fasciae There is a groove in the midline in which are palpable the spinous processes there are also two lateral areas in which are located many muscles.

Normally the back is a symmetric structure with the part on each side of the spine equal in size and outline (Figs. 1 and 2) This symmetry is evident both in the upright and in the forward-bent position. An asymmetric back indicates deformity it can usually be perceived in the upright position, and is always manifest in the forward bent position.

In the lateral view, the intervertebral foramina appear oval in shape, and are small in the cervical, larger in the thoracic, and largest in the lumbar region

The spine bears the weight of the head shoulders and thoracic and abdominal contents, and transmits this weight through the sacroiliac joints to the pelvis and thence to the lower limbs

In general, the vertebrae are alike in that each one except the first consists of an anterior solid or weight bearing part called the body or centrum, and a hollowed posterior segment or arch which encircles and protects the spinal cord The posterior arch has a number of projections or processes especially the articular processes a superior and inferior one on each side allowing for contact and motion between adjacent vertebrae

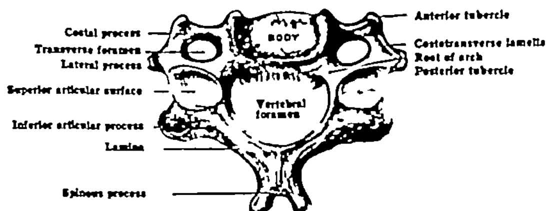


FIG 4 Cervical vertebra cranial view (71) vertebral body relatively small vertebral foramen large numerous processes

In the different sections of the spine however the vertebrae are modified and adapted to the needs of the respective parts of the trunk so that the vertebrae in the cervical dorsal and lumbar regions, respectively exhibit distinctive modifications. At the junctions of the sections namely, the cervicodorsal dorsolumbar and lumbosacral segments, the vertebrae have some of the characteristics of the two contiguous sections thus effecting a gradual transition from one section to another

Cervical Vertebrae A description of the dominant characteristics of one cervical vertebra (Fig 4) will suffice for our purposes. The body, or solid portion is rectangular with its transverse diameter greater than its antero posterior Two lateral masses join posteriorly to form the spinous process, each mass presenting near the body a transverse process perforated for the passage of the vertebral artery and vein Behind the transverse process is the articular process, a thickened portion of bone with an articular facet above and below These articular surfaces are at an oblique angle of about 45 degrees (Fig 5) the superior facet facing upward and backward and the

formed by the first four thoracic vertebrae The third pyramid much the longest is the result of the increase in size from the fourth thoracic to the fifth lumbar ver

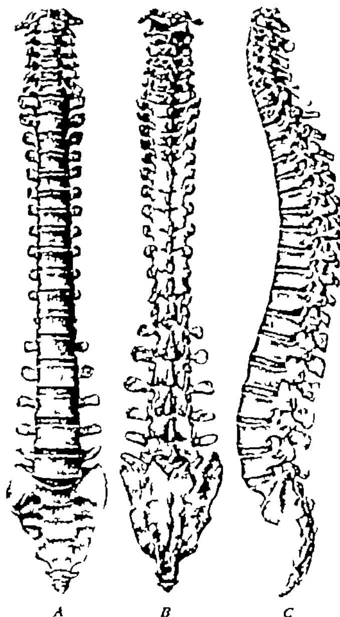


FIG 3 Normal spine (83) A Anterior view B Posterior view C Lateral view

tebra and the fourth which is inverted is produced by the rapid contraction of the sacral and coccygeal vertebrae

Viewed dorsally the spinous processes project in the midline On each side is the vertebral groove the floor of which is formed in the cervical and lumbar regions by the laminae and articular processes and in the thoracic region by the laminae and transverse processes

Fig 5 Cervical vertebrae lateral view obliquity of articular facets

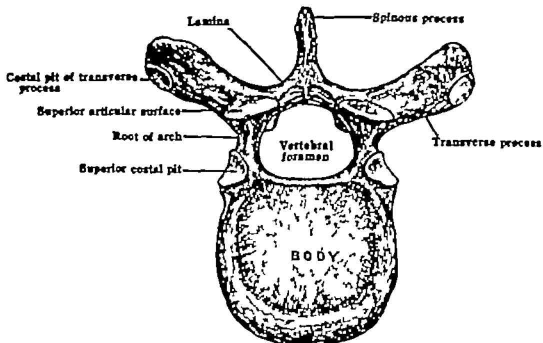


Fig 6 Dorsal vertebra, cranial view (71)

inferior downward and forward The spinous processes project backward are short and bifid with the seventh process longer than the rest.

The vertebral foramen is described (71) as "triangular with rounded angles; it is larger than that of the thoracic and lumbar vertebrae, in adaptation to the cervical enlargement of the spinal cord and to the greater mobility of the cervical region of the column.'

Thoracic (Dorsal) Vertebrae These vertebrae (Fig 6) are larger than those in the cervical region Each vertebra consists of a body anteriorly and two lateral masses which join posteriorly to form an arch within which is the vertebral foramen The body is rectangular with the anteroposterior diameter somewhat longer than the transverse On either side of the body are two partial articular facets one at the upper and the other at the lower border When the vertebrae are superimposed, the articular facets form shallow saucer like articular surfaces for articulation with the corresponding ribs (Fig 7) The upper and lower surfaces of the body are rough for the attachment of the intervertebral disks The arch of the vertebra made up by the two lateral masses has seven processes—one spinous, two transverse and four articular—each of which has an articular facet These facets are in a perpendicular plane, the upper facing backward and the lower one forward The transverse processes present at their outer extremities, articulating facets, one on each process for the corresponding rib The spinous processes are long and project sharply downward overlapping each other 'When the vertebrae are articulated, the series of vertebral foramina constitute chiefly the spinal or vertebral canal (canalis vertebralis) in which are lodged the spinal cord and its membranes the roots of the spinal nerves the posterior longitudinal ligament and the blood vessels supplying these structures (71)

Lumbar Vertebrae In size the lumbar vertebrae (Fig 8A B) are much larger than either the cervical or dorsal vertebrae The transverse diameter of the body is greater than the anteroposterior and its anterior border is longer than the posterior The body has no facets, since unlike the dorsal vertebrae the lumbar vertebrae make no contact with the ribs The articular processes lie in a sagittal plane the upper facets facing inward and the lower facets outward. The spinous processes are short thick, strong, and point directly backward it is of practical importance that the spinous process of the fifth lumbar vertebra is very small The vertebral foramen is triangular larger than the dorsal but not as large as the cervical foramen.

Sacrum It is triangular in shape its base upward an articular process on either side of its superior surface for articulation with the last lumbar vertebra, and an irregular articular surface on each lateral mass for articulation with the iliac bones of the pelvis (Fig 9) The surface between the median and lateral sacral crests presents a shallow concavity known as the

Fig 5 Cervical vertebrae lateral view obliquity of articular facets

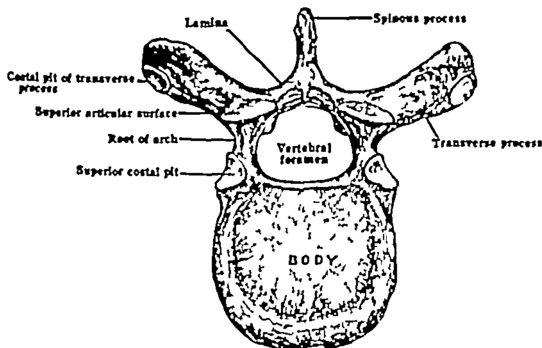


Fig 6 Dorsal vertebra cranial view (71)

sacral groove, continuous cranially with the vertebral groove of the movable part of the column and like it, lodging the multifidus muscle' (71)

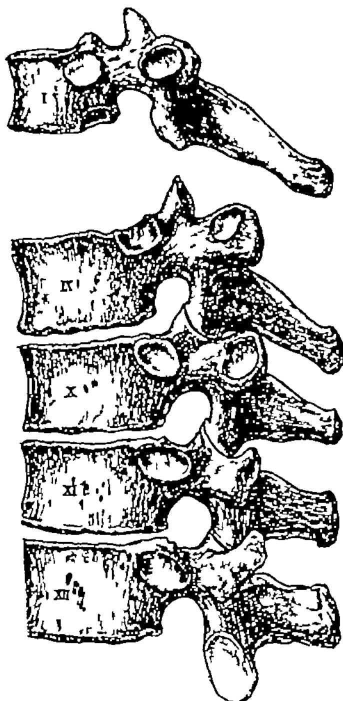


FIG 7 Dorsal vertebrae lateral view (71)

The surface between these crests is rather smooth and offers good bone for chip grafts in a lumbosacral spine fusion. The spinous processes of the upper

sacrum while short, are useful for anchorage of bone grafts or metal plates in spine fusion operations

Coccyx This bone is vestigial, and is of no practical importance in scoliosis

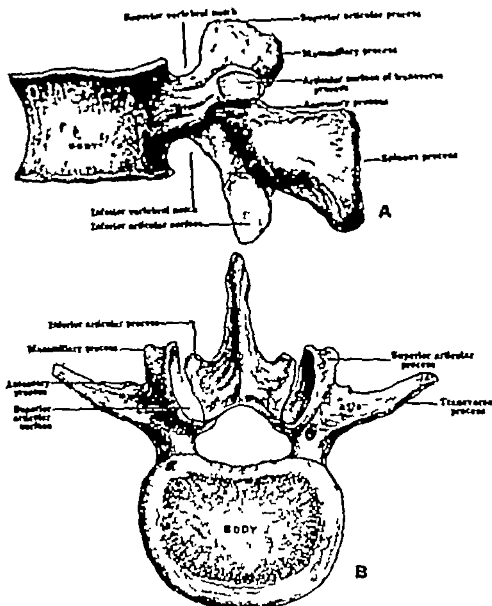


FIG 8 Lumbar vertebra (71) A Lateral view B Cranial view

Variations in Vertebrae Congenital vertebral variations fall into two classes those of symmetry or number, and those of asymmetry or morphology Symmetric variations are not a cause of scoliosis, while asymmetric or morphologic variations frequently cause a scoliosis

The *symmetric* variations are of three kinds (*1*) variations in number, (*2*) variations in cervical or lumbar ribs, and (*3*) fused ribs In the *cervical*

region variations are infrequent occasionally the occiput and atlas are fused or there are only sIx cervical vertebrae The seventh or even the sixth vertebra may have ribs attached to it. Instances have been reported of as few as two and as many as eight cervical vertebrae and rarely, there are no cervical vertebrae at all (Klippel Feil syndrome)

Variations in the *dorsal* vertebrae are fairly frequent The commonest numerical variation is the presence of eleven or of thirteen vertebrae, accompanied by a corresponding change in the number of ribs When there

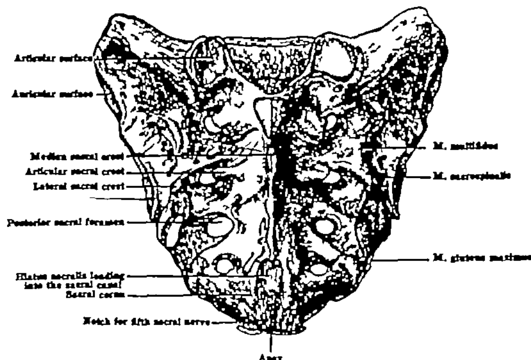


FIG 9 Sacrum (71)

is a variation in the number of ribs, a concomitant change in the number of dorsal vertebrae is not always present.

The most frequent change in the *lumbar* vertebrae is the presence of four or of six vertebrae Two or more lumbar vertebrae or the last lumbar vertebra and the sacrum may be fused. The transverse processes, es-pecially of the last lumbar vertebra, may vary in size and one or both of them may articulate with or be fused to the sacrum.

The segments forming the *sacrum* may vary in number from one to seven The first segment may be completelj detached from the sacrum. The posterior arches of the upper sacral segments may remain ununited. In all these changes, the two sides of the vertebral column are equal in size and conformation and the back retains its symmetry Other structural vari-ations may be abnormal breadth or length one or both sides may be

fused with the last lumbar vertebra, one side may be underdeveloped and may not articulate with the ilium However, I have never encountered any peculiar anatomic variation of the sacrum which by itself has been definitely responsible for a scoliosis

Of the many anomalous *morphologic* variations in the vertebrae some are of particular interest to the student of scoliosis A striking anomaly is *hemivertebra*, the presence of a half vertebra in either the dorsal or lumbar area "Such vertebrae' have a wedge-shaped half body, to which are attached a half arch with a transverse process superior, and inferior articular processes and half a spinous process As a rule, a half vertebra is ankylosed to the adjacent vertebrae' (71)

A more common peculiarity is *spondylolysis*, a solution in the continuity between the articular processes, seen frequently in the lumbar area and less frequently in the dorsal region The ventral part is composed of the body, carrying the roots transverse, and superior articular processes the dorsal portion is made up of the laminas, and spinous and inferior articular processes. This solution of bone continuity at the pars interarticularis is the basis for a spondylolisthesis

Lack of fusion of the lateral masses posteriorly, resulting in a *spina bifida* is common in the last lumbar and first sacral segments but it may be found anywhere in the spinal column In this anomaly the bony posterior arch is incomplete and there is no spinous process.

Any number of anomalies or vertebral variations may be present in the same spine The morphologic variations of the vertebrae are frequently encountered in congenital scoliosis and may be its proximate cause

The fifth lumbar vertebra is subject to so many morphologic variations that it is difficult to describe the normal state (*1*) It may have a spina bifida (*2*) Its transverse processes may be symmetric in shape and size or the two processes may differ radically one transverse process may be very much larger than the other, and be free or articulate with or be fused to the sacrum both transverse processes ordinarily small in size may be large and both may articulate with or be fused to the sacrum (*3*) The apophyseal joints usually symmetric are frequently asymmetric, one joint remains in the sagittal plane the other is in the coronal plane, or, both joints may be in the coronal or in an oblique plane (*4*) The body may be split one part being fused to the fourth lumbar and the other forming an irregular wedge-shaped mass

Vertebral Body The structure of the vertebral body is practically the same throughout the spinal column. Normally it consists of a thin shell of compact bone within which is an extremely vascular spongy bone containing vertical and transverse lamellas or bone plates distributed uniformly and almost symmetrically This differs markedly from the dis-

region variations are infrequent occasionally, the occiput and atlas are fused, or there are only six cervical vertebrae The seventh or even the sixth vertebra may have ribs attached to it. Instances have been reported of as few as two and as many as eight cervical vertebrae and, rarely, there are no cervical vertebrae at all (Klippel Feil syndrome)

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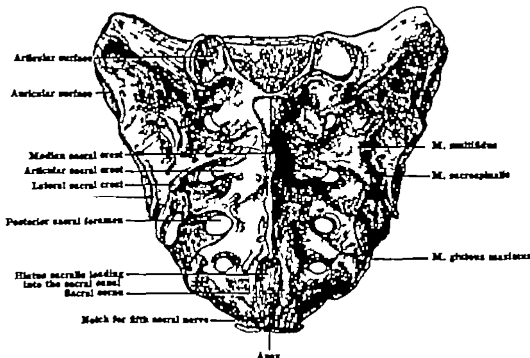


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Vertebral Body The structure of the vertebral body is practically the same throughout the spinal column Normally, it consists of a thin shell of compact bone within which is an extremely vascular spongy bone containing vertical and transverse lamellas or bone plates, distributed uniformly and almost symmetrically This differs markedly from the dis-

tribution at or near the apex of a scoliotic curve. The posterior arch of the vertebra and the structures in the vertebral canal also have an abundant blood supply The vascularity of every segment of the spinal column (Fig 10) is of great value in such conditions as a fracture or infection of a vertebra, but it is a decided hazard during surgery on the spine

Intervertebral Disks These fibrocartilaginous structures (Fig 11), twenty three in number are located between and unite the vertebral bodies from the axis to the sacrum They vary in size and shape conforming to the vertebral bodies they unite Each disk is composed of the annulus fibrosus (a peripheral circumferential fibrous section) and the nucleus pulposus (a central elastic mass) The strong tough annulus fibrosus contains fibrous tissue and fibrocartilage, and is firmly attached to the adjacent vertebral bodies and the anterior and posterior longitudinal ligaments. Some fibers extend beyond the vertebral margins, and are attached to the anterior and lateral surfaces of the bodies The lamellas toward the center of the annulus fibrosus are incomplete less firm and less distinct than the rest as they near the pulp, they gradually assume its characteristics, they become less fibrous and contain cartilage cells in their structure The nucleus pulposus is a fibroelastic mass or ball located somewhat behind the center of the disk and held in position by the annulus fibrosus it constitutes a pivot around which the vertebral bodies can twist and incline Articular cartilage separates it from the adjacent bone The fibroelastic structure of the disks allows motion between the vertebrae, and their elasticity and compressibility relieve the spine of the jars incident to weight bearing walking, and jumping The disks account for about a fourth of the length of the spinal column exclusive of the first two vertebrae Their thickness, shape and size vary in different sections of the spine in fact no disk is of uniform thickness. In the cervical and lumbar regions the disks are much larger than in the dorsal thus allowing greater mobility at the former points. The acrobatic capacities of some individuals are the result of hypermobility of the cervical and lumbar regions and unusual flexibility at the hips. The anterior parts of the disks are thicker than the posterior in the cervical and lumbar regions while in the dorsal region the reverse is true These differences help impart the characteristic physiologic curves of these sections of the spine

Ligaments The anterior and posterior common ligaments run along the anterior and posterior surfaces of the bodies of the vertebrae and are attached to them and to the intervertebral disks The anterior common ligament is broader thicker and stronger than the posterior ligament. The posterior arches of the vertebrae are connected to one another and to adjacent bony tissues by numerous short but strong ligaments. At the sacroiliac joints, there are numerous intersecting ligaments, some thin others thick and strong which bind the sacrum very firmly to the iliac

Post vertebral plexus

Ant and posterior longitudinal sinuses

Lumbar v

Asc lumbar v

Intervertebral v

Ant vertebral plexus

Basivertebral vein

FIG 10 Vertebral venous plexus (82)

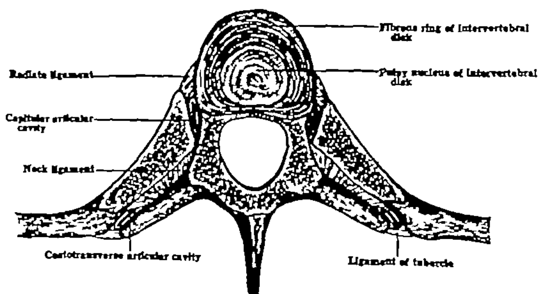


FIG 11 Horizontal section through an intervertebral disk and vertebral articulations of a pair of ribs (41) Walls of articular cavities are represented schematically

bones (Fig 12) This firm union, together with the wedge shape of the sacrum and the irregularity of the articulating surfaces allows very little motion in the sacroiliac joints As a result, differences in the lower limbs

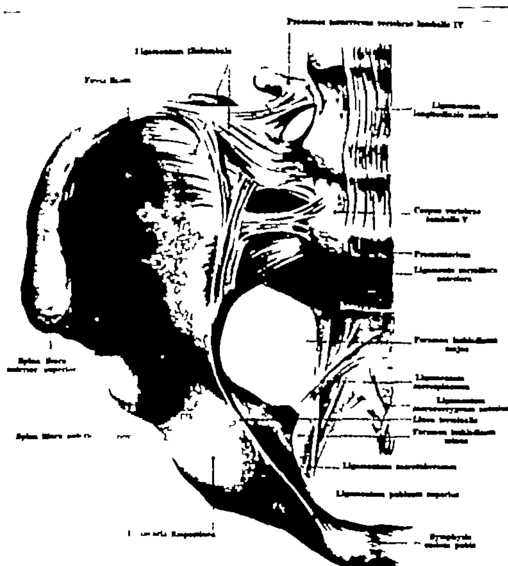


Fig 12 Ligaments of the right half of pelvis (84)

such as unequal length or a unilateral contracture affect the curve of the spine and the contour of the back.

Blood Supply of Spinal Column

The vertebrae derive their blood supply from the main arteries in their vicinity The cervical vertebrae are supplied by the lateral spinal branches

of the vertebral arteries. Gray's *Anatomy* (33) gives the following description

"Spinal branches (*rami spinales*) enter the vertebral canal through the intervertebral foramina and each divides into two branches Of these one passes along the

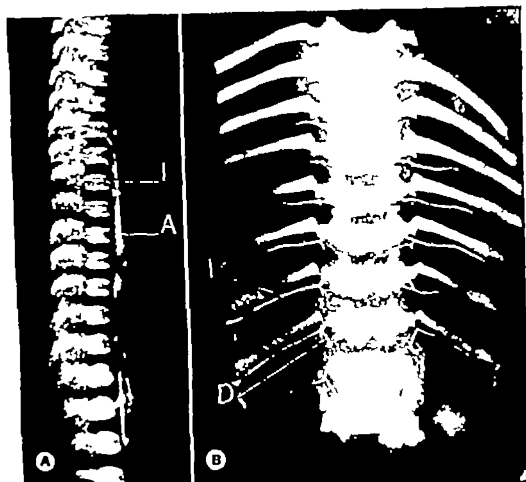


FIG 13 Full term fetal spinal column (99) A Lateral roentgenogram with opaque vascular injection of aorta notching of anterior surfaces of vertebral bodies diminished density of midportions longitudinal anastomosis of arteries in neural canal clearly visualized (*A* aorta *I* intercostal artery) B Anteroposterior view of same column after removal of aorta anastomosis of intercostal arteries and incomplete ossification of cartilaginous neural ring (*I* intercostal artery *D* dorsal division of artery)

roots of the nerves to supply the medulla spinalis and its membranes anastomosing with the other arteries of the medulla spinalis the other divides into an ascending and a descending branch which unite with similar branches from the arteries above and below so that two lateral anastomosing chains are formed on the posterior surfaces of the bodies of the vertebrae near the attachment of the pedicles From these anastomotic chains branches are supplied to the periosteum and the bodies of the vertebrae and others form communications with similar branches from the opposite

side from these communications small twigs arise which join similar branches above and below to form a central anastomotic chain on the posterior surface of the bodies of the vertebrae

The dorsal vertebrae are supplied by branches from the intercostal arteries derived from the thoracic aorta The distribution of the spinal branches of the intercostal arteries is similar to that of the lateral spinal branches of the vertebral artery According to Willis (99)

the paired segmental vessels which become intercostal and lumbar arteries extend dorsally from the aorta and cross the middle of the lateral surfaces of the vertebral bodies one on each side The larger element of each runs laterally anterior to the lower border of the ribs and the transverse processes to supply the thoracic and abdominal walls A large branch is given off in the trough formed by the vertebral bodies and transverse processes It traverses the intervertebral foramen and divides into three terminal branches one to the posterior surfaces of the two adjacent vertebral bodies another to the spinal cord and its membranes, reaching the cord by way of the ligamentum denticulatum and the third to the posterior vertebral processes and surrounding soft structures [Fig 13]

The first branch of the dorsal division of the intercostal or lumbar artery divides within the spinal canal one terminus running upward and medially across the posterior surface of the vertebral body under the posterior spinal ligament to enter a foramen at about the center of the body The other terminus runs downward and medially to a similar entrance in the center of the body of the next distal vertebra Thus there are four diagonal arteries two from each side converging to enter the center of the posterior surface of each vertebra They may enter through a common foramen or each may have its own individual entrance At this point the bone structure is cancellous or even cavernous, and the arteries may coalesce or remain more or less separate From here their branches radiate to all parts of the centrum [Fig 14]

The notch shown by roentgenograms on the anterior surface of the vertebral body sometimes referred to as the fovea centralis is due to relative lag in calcification of the cartilaginous centrum, not to the entrance of nutrient arteries The foramina seen on the anterior surface of the centra are exits for veins not entrances for arteries

The nutrient arteries enter the posterior foramina from a layer of loose areolar tissue beneath the posterior spinal ligament

The point of particular and practical interest as it relates to scoliosis is that the vertebrae and especially the bodies, have an abundant blood supply This fact must be kept in mind during any surgery on the spinal column

The intimacy between the thoracic aorta and the dorsal vertebrae is especially noteworthy

The thoracic aorta is contained in the posterior mediastinal cavity It begins at the lower border of the fourth thoracic vertebra where it is continuous with the aortic arch and ends in front of the lower border of the twelfth at the aortic hiatus in the diaphragm At its commencement it is situated on the left side of the vertebral

column it approaches the median line as it descends and at its termination lies directly in front of the column The vessel describes a curve which is concave forward and as the branches given off from it are small its diminution in size is inconsiderable (33)

By the same token when the spine undergoes a scoliotic deformity the aorta becomes correspondingly distorted.

The lumbar vertebrae are supplied by the spinal branches of the lumbar arteries which are derived from the abdominal aorta These branches are distributed in the same manner as the spinal branches for the other verte-

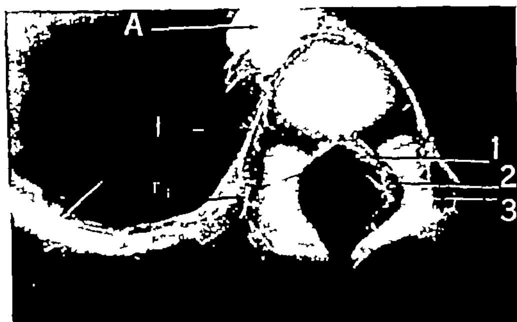


Fig 14 Thoracic vertebra (90) A Vertical view many fine arteries penetrating periosteum and perichondrium (*A* aorta *I* intercostal artery *D* dorsal division *1 2* and *3* first second and third branches of dorsal division)

brae The abdominal aorta extends down to the fourth lumbar vertebra and hugs the lumbar segment of the spinal column as the thoracic aorta does in the dorsal area.

The middle sacral artery is a small vessel which arises from the back of the aorta a little above its bifurcation It descends in the mid line in front of the fourth and fifth lumbar vertebrae the sacrum and coccyx, and ends in the glomus coccygeum (coccygeal gland) On the last lumbar vertebra it anastomoses with the lumbar branch of the iliolumbar artery In front of the sacrum it anastomoses with the lateral sacral arteries and sends offsets into the anterior sacral foramina (33)

Thorax

A cage composed of muscle bone and cartilage the thorax (Fig 15 A–C) contains chiefly the organs of respiration and circulation It is funnel

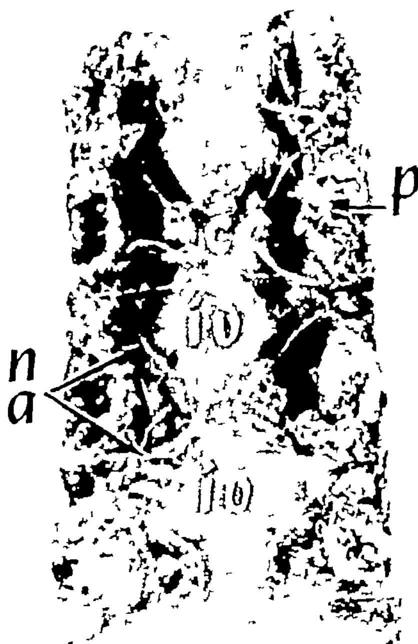


Fig 14 B Posterior surface of vertebra after removal of neural arches (*p* amputated pedicle stump *c* vertebral centrum *iv* intervertebral disk area (*c* and *iv* are covered by posterior spinal ligament) *n* and *a* nutrient arteries the first branches of the dorsal division of an intercostal or lumbar artery)

shaped being narrow above, wide below, and much longer in the back and on the sides than in front It is flattened from in front backward so that the transverse diameter is greater than the anteroposterior diameter

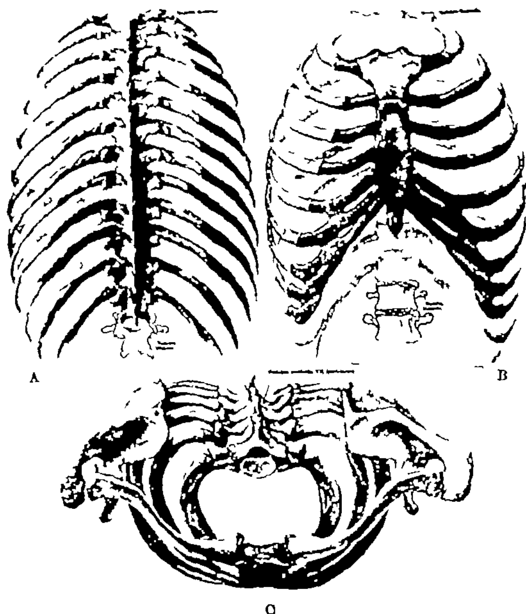


FIG 15 Thorax (81) A Posterior view B Anterior view C View from above

The thorax is made up of the dorsal vertebrae the ribs cartilages and sternum joined together by muscles and ligaments The ribs twelve symmetrically arranged on each side are divided into true and false ribs The upper seven are spoken of as true ribs because they are attached directly to the sternum through their costal cartilages The lower five are false ribs, the eighth ninth and tenth ribs being attached to the sternum through

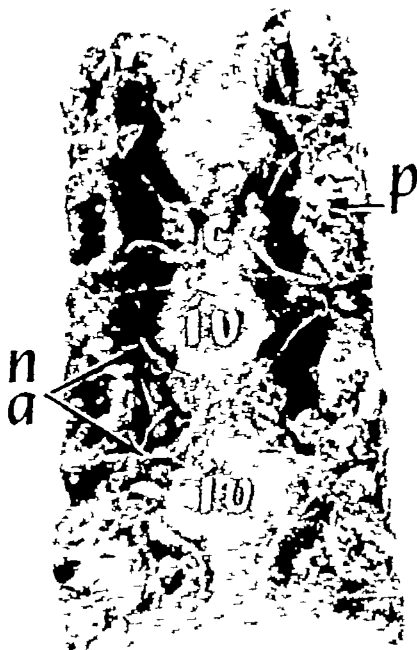


Fig 14. B Posterior surface of vertebra after removal of neural arches (*p* amputated pedicle stump *c* vertebral centrum *iv* intervertebral disk area (*c* and *iv* are covered by posterior spinal ligament) *n* and *a* nutrient arteries the first branches of the dorsal division of an intercostal or lumbar artery)

of the scapulas to the spine changes and they become unequally prominent The shoulders are displaced so that they are no longer on the same level or in the same plane. In fact, since displacement of the shoulders is such an evident abnormality, one of the earliest signs by which a scoliosis is recognized is the so-called "high shoulder," that is, a difference in the level of the shoulders

Muscles

The musculature of the trunk consists of groups of muscles, many of which overlap, extending from the head to the pelvis In a general way, the trunk muscles may be divided into an anterior and a posterior group Beginning at the occiput, the anterior group runs to the top of the chest and via the chest wall becomes continuous with the abdominal muscles The posterior group extending along, and largely in back of, the spine from the occiput to the pelvis includes muscles which are attached to the shoulder and pelvic girdles.

Each muscle or muscle group has its special action, and would in itself cause a special and characteristic motion Normally, however many muscles act in concert, and a given motion of the trunk or spine is the result of the combined and coordinated action of many muscles Maintenance of the erect position is dependent upon the automatic, instinctive, and coordinated action of practically all of the trunk muscles Thus, unilateral weakening or paralysis of the abdominal or trunk muscles as after poliomyelitis is sufficient to disturb the balance of the vertebral column and may lead to scoliosis.

The rôle of the muscles in the mechanism of scoliosis is not yet completely understood for example, in a curvature to the right in the dorsal region due to muscular paralysis it is impossible as a rule, to specify whether the muscles of the right or left side of the back are paralyzed Nevertheless, despite our ignorance of the precise manner in which the muscles affect the production of scoliosis, there is no doubt that they play a significant part in this condition

Experiments carried out by Carey (18) led him to conclude that the functional integrity of the blood nerves muscles tendons bones and joints was essential to maintain the motor system of the back in normal balance Focal muscular weakness and undernourishment might, in his opinion cause an imbalance which would result in a myogenic scoliosis More recently Schwartzman and Miles (78) have studied the effect of muscle imbalance on the alignment of the vertebral column in rats and mice This imbalance was produced in various ways (*1*) unilateral excision of groups of symmetric muscles influencing the movements and position of the vertebral column (*2*) bilateral excision of symmetric muscles (*3*)

the cartilage of the seventh rib The two lowest ribs are unattached the so-called floating or free ribs In general their course traced from the spinal column, is at first backward then outward and slightly downward then forward, outward and downward and in the front of the chest they turn inward forward and downward to their junction with the costal cartilage and sternum The downward inclination of the ribs increases from above downward the first rib being almost horizontal The inclination of corresponding ribs on each side is the same similarly, corresponding inter costal spaces are of the same size The downward inclination of the ribs causes their terminal portions in front to be at a much lower level than their posterior ends.

The thorax consists of many tissues these however, are so intimately united that it may be considered as a single structure and a change in the shape or position of one part will result in a change in another part. If the left side of the chest in front is pressed backward, the left posterior part will bulge backward this is especially well marked during inspiration. Similarly if the right side of the chest is compressed laterally the left side will become correspondingly more prominent The ease with which the chest yields to pressure is an exceedingly important factor in the correction of scoliosis. Not only does pressure on one part of the chest influence another part but, more particularly pressure on a rib influences the corresponding vertebra Thus, scoliosis has been produced in normal dogs by long continued pressure on the ribs at some one point (101) and in the cadaver it has been demonstrated that pressure on a rib caused motion in the corresponding vertebra.

The costal cartilages, ribs, costovertebral joints and ligaments are all elastic structures. Hence pressure applied to the chest wall and intended to affect the vertebrae reaches them in very much reduced force Conversely the degree of pressure necessary to correct a deformity of the spine must be far greater when exerted upon some portion of the chest wall than would be necessary could it be applied directly to the spine The upper part of the chest is surrounded by the shoulder girdle—the clavicles in front the strong muscles forming the axillary folds the scapulas and scapular muscles behind all these hinder and make ineffective any corrective pressure intended for the upper ribs These anatomic conditions make it impossible to alter or control high dorsal or cervicodorsal abnormal curves.

Shoulders

Normally the shoulders are on the same level and in the same frontal plane. The scapulas are or should be equally prominent and equidistant from the vertebral column. When the chest becomes deformed the relation

The angle of pelvic inclination varies greatly, but a fair average is 50 degrees in the adult and about 35 degrees in children The iliac crests are normally on the same level, as are also the sacroiliac joints and the

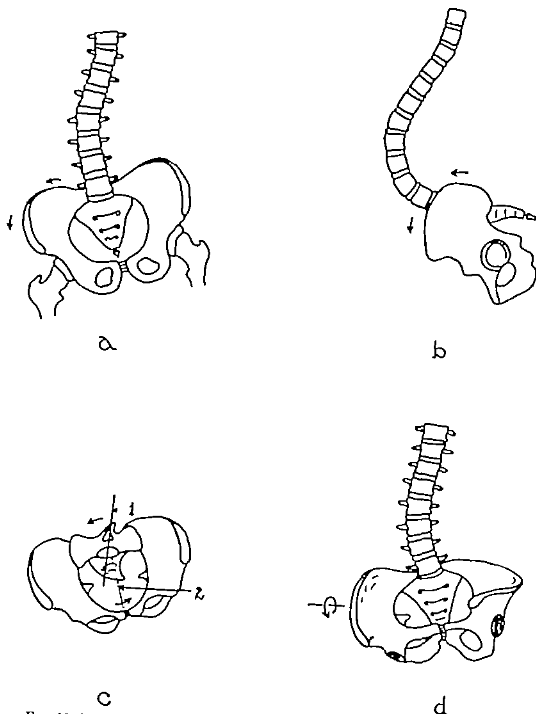


FIG 16 Different types of rotation of pelvis (57) A Lateral tilt on an anteroposterior axis B Anteroposterior motion on a transverse axis C Rotation around a longitudinal axis D Torsion of one innominate bone on the other around an axis going through the sacroiliac joint

operative release of muscles and prevention of their healing The results of their study led these authors to conclude that scoliosis can be produced by selective muscle imbalance which simulates the mechanical condition of paralytic scoliosis.

Pelvis and Its Inclinations

The pelvis may be considered as an osseous basin consisting of the sacrum and coccyx posteriorly and the innominate bones laterally Anteriorly the innominate bones are joined together by the symphysis pubis. The bones forming the pelvis are united by numerous exceptionally strong ligaments, allowing little motion The two halves are similar in structure and should by symmetric in conformation The sacrum is in the middle of the posterior part of the pelvic girdle and the pelvic bones are joined by the interpubic fibrocartilage in the middle of the anterior part The contour of the pelvic cavity is symmetric the two halves being of the same size and shape Under normal conditions the bones forming the pelvis are so thoroughly bound by ligaments that the pelvis acts as a whole, moving laterally or anteroposteriorly as one bone while retaining its symmetry However under the stress of pathologic conditions, such as rickets osteomalacia poliomyelitis, or tuberculosis or as a consequence of a severe scoliotic deformity one side of the pelvis may give way and become contracted or larger than the other side, the pelvis then becomes asymmetric Rarely there is a congenital unilateral contraction of the pelvis Normally, the anterior superior iliac spines are on the same level

The pelvis is the intermediary between the trunk and lower limbs transmitting the weight of the trunk to the lower limbs and traction and pressure forces from the lower limbs to the spine and vice versa. Many of the muscles and the fasciae of the back and abdomen are attached to the pelvis, while the muscles which take origin from the pelvis attach either to the back or to the lower limbs Normal weight bearing the erect posture, and effective function of both the spine and lower limbs depend upon a practically normal physical relation of the pelvis to the trunk and lower limbs For example, if the right lower limb is shorter than the left the pelvis when the individual stands on both feet tilts downward on the right side and carries with it the lumbar vertebrae forming a right lumbar curve Since the individual instinctively seeks an upright position the dorsal vertebrae form a compensatory curve to the left Thus a shortened limb initiates a scoliosis mediated via the pelvis Similarly when there is a unilateral spasm or contracture of the quadratus lumborum the pelvis is pulled up on that side and not only a scoliosis but also a disturbance in the function of the lower limbs result

The normal position of the pelvis is at an angle to the horizontal plane the posterior part is higher than the anterior surface or symphysis pubis

arch with the body is known as the neurocentral synchondrosis, and is not actually obliterated for several years after birth

The laminae unite during the first year after birth and by the gradual extension of ossification into the various processes, the vertebrae have attained almost their full size by the time of puberty Subsequently the secondary centers appear in the cartilaginous extremities of the spinous and transverse processes and in the cartilage on the cranial and caudal surfaces of the bodies forming in each vertebra two annular plates thickest at the circumference and gradually thinning toward the central deficiency The epiphyses appear from the fifteenth to the twentieth year and join with the vertebra by the twenty fifth year (Fig 18)

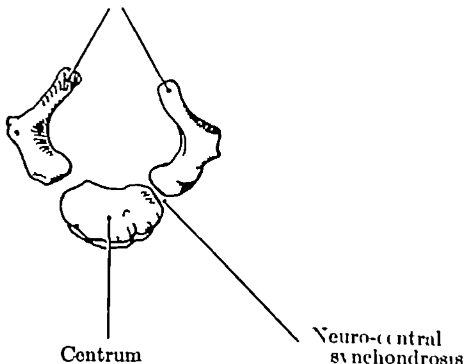


Fig 17 Vertebra at birth (32)

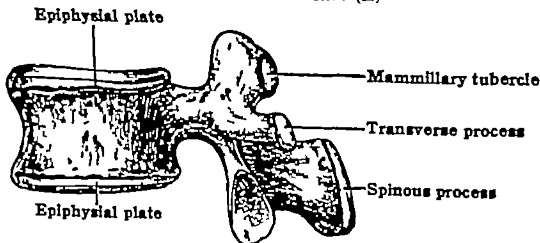


Fig 18 Lumbar vertebra at eighteenth year with secondary centers (71)

anterior superior iliac spines. Since the pelvis is placed between two movable sections namely, the suprasacral portion of the spine above and the hip joints below, movement of the pelvis is possible in several directions. The commonly accepted motions are the following (Fig 16 A–D) (*1*) The pelvis may tilt laterally to the right and left, on an anteroposterior axis. (*2*) The pelvis may tilt in an anteroposterior direction on a transverse axis, increasing or decreasing the anteroposterior pelvic inclination. When the angle is increased physiologically or because of disease or deformity the anterior lumbar curve or lordosis is increased conversely, when the pelvic angle is decreased, the lumbar curve is flattened Lovett (62) is of the opinion that changes in inclination of the pelvis must form an important element in so-called round shoulders (*3*) The pelvis may rotate around a longitudinal axis (*4*) There may be a torsion of one innominate bone on the other around an axis going through the sacroiliac joint In a study of the pelvis in paralyzed women (57) such torsion was found in 7 of 101 cases All 7 suffered from severe scoliosis in 5 there was advanced paralysis of both lower limbs, in 2 there was advanced paralysis of one lower limb, 6 had shortening on the side of the torsion and 1 on the opposite side.

The relative position and inclination of the pelvis may thus be altered by physical and functional derangements either above or below it Conversely by changing the position of the pelvis one may possibly influence the function and morphology of adjacent tissues, such as the lumbar vertebrae The student of scoliosis must therefore know accurately the anatomic relations between the pelvis, the spine and the lower limbs.

Embryology

Scoliosis is chiefly a problem of the period of growth, a brief review of the growth and development of the vertebrae will therefore be useful. The following is quoted from Morris' *Human Anatomy*

> The ossification of a vertebra takes place in cartilage from three primary and five secondary centers The three primary centers appear one in the body and two in the arch about the seventh week of intrauterine life In the thoracic region the nucleus for the body appears first but in the cervical region it is preceded by the centers for the arch The nucleus for the body soon becomes bilobed and this condition is sometimes so pronounced as to give rise to the appearance of two distinct nuclei Indeed the nucleus is very rarely double and the two parts of the body may remain separate throughout life The bilateral character of the nucleus is further emphasized by the occasional formation of half vertebrae The centers for the arch are deposited near the bases of the superior articular processes and give rise to the roots laminae articular and the greater parts of the transverse and spinous processes

A typical vertebra (Fig 17) at birth to quote the same source

> consists of three osseous pieces—a body and two lateral masses that constitute the arch, the parts being joined together by hyaline cartilage The line of union of the

Side bending rotation is a combined movement in which both side bending and rotation of the spine are present. In any given motion of side bending rotation, either of these elements may predominate, but it is generally accepted that neither occurs independently. Abbott (1) listed five pure or primary movements of the spine, namely, flexion, extension, side bending, rotation, and torsion. Theoretically, the latter three may be possible as isolated distinct movements but practically they are not demonstrable as such. When an individual twists his back, there is always a certain degree of lateral bending of the spine. Similarly, when an individual bends to one or the other side, there is some accompanying rotation.

The degree and type of side bending rotation vary in the different regions and in different positions of the spine. In the flexed position side bending occurs almost entirely in the dorsal region, the lumbar vertebrae being apparently so locked as to oppose motion. In this position, the vertebrae rotate toward the convexity of the lateral bend, as indicated by the direction of the spinous processes. In the erect position side bending occurs chiefly at the dorsolumbar junction. In the hyperextended position side bending is practically limited to the lumbar region. In both the erect and hyperextended positions side bending, according to Lovett (62), is accompanied by rotation toward the concavity of the lateral bend.

'Rotation accompanying side bending is therefore of a different type in the flexed position of the spine from what it is in the erect or hyperextended position.

In flexion of the whole spine bending is accompanied by rotation of the vertebral bodies to the convexity of the lateral curve, the characteristic of the dorsal region.

In the erect position and in hyperextension of the whole spine side bending is accompanied by rotation of the vertebral bodies to the concavity of the lateral curve, the characteristic of the lumbar region.

These conclusions are true of the normal spine but they do not necessarily apply to a deformed scoliotic spine.

In this regard, some writers believe that rotation is always toward the convexity of the lateral bend in all parts of the spine. At any rate, in structural scoliosis the vertebrae are rotated toward the convex side of the curve in both the dorsal and lumbar regions.

Mechanics of Scoliosis

The spine supports the head and trunk; it is mobile to permit changes in position of the trunk; it protects and supports the spinal cord and the roots of the peripheral nerves; and it serves as a point of attachment for the muscles of the back, some of which extend to the shoulders and pelvis. The spine is able to perform these various functions because it is made up of a series of bony segments with interposed fibroelastic cartilaginous disks, all joined together to form a column with a compound anteroposterior

The above is a description of the average type of ossification. Some variations occur but none of special significance for the present study What is important and may be even more so in the future is a knowledge of the bilobed nature of ossification of the body, and the appearance in the body of the secondary centers of ossification for the superior and inferior surfaces. Disturbances in the development of the superior and inferior plates may, in the opinion of some (6) account for the origin of a scoliosis, and may, according to the experimental proof of others (13) be utilized as a positive therapeutic procedure

The epiphyses of the iliac crests appear through secondary centers of ossification at puberty and are joined to the bodies of the iliac bones between the twentieth and twenty fifth years This fact is mentioned because some insist that active treatment of scoliosis must be continued until the iliac epiphyses are complete Their argument is based on the assumption that so long as the epiphyses of the iliac crests are incomplete there is inadequate stabilization of the spine and the deformity may increase.

Physiology

Motions of the Spine

The spine is a flexible, segmented column curved in the anteroposterior plane Three factors influence the motions of the spine, namely the normal anteroposterior physiologic curve of the spine the presence of compressible elastic fibrocartilages between the vertebrae (intervertebral disks) of varying thickness and shape and the articular processes the facets of which have characteristic positions or angles of inclination in different parts of the spine

There is general agreement that the motions of the spine are (*1*) flexion or forward bending (*2*) extension, or backward bending and (*3*) side bending rotation I follow closely the teaching of Lovett in the section that follows.

Flexion is a pure motion in the anteroposterior plane All parts of the spine are capable of it, but it is freer in the lumbar and dorsolumbar regions than in the cervical and dorsal regions In extreme flexion the static lumbar curve may be obliterated in children (and even in adults in such pathologic states as sciatic scoliosis) it may become convex backward Flexion of the head and rotation of the pelvis may exaggerate the apparent degree of flexion of the spine.

Extension is also a pure motion in the anteroposterior direction. It is most free in the lumbar and eleventh and twelfth dorsal vertebrae In the movements of the spine the last two dorsal vertebrae act like lumbar vertebrae This is due to the transitional character of these bones especially their articular facets and the corresponding unattached or floating ribs.

continuously and are normal, although at any one moment the spine may be curved, the individual can voluntarily assume a normal attitude with the spine in the midline However, if for any reason the body is so held that one part of the spine is persistently deviated laterally, and hence rotated to the convex side of the curve the external conformation and the internal structure of the vertebrae alter in response to their new obligation (Wolff's law (100)) Once this structural change is accomplished, the individual can no longer hold his spine in the midline nor the trunk in a



FIG 19 Roentgenograms illustrating compensatory curve A Patient in recumbent position left dorsolumbar scoliosis B Patient in upright position single curve changed to double curve left dorsolumbar curve changed to right dorsal left dorsolumbar the short upper curve being compensatory

symmetric position a fixed curvature has been established Concurrently the structure of the vertebrae in the compensatory curve changes Experimentally a fixed scoliosis has been produced by means of forced, continuous malposition of the trunk and spine by Wullstein (101) first, and by others since then

Functional curvatures occur much more frequently than organic ones Why some functional curves change into organic curves while others remain unchanged is still a mystery Only infrequently is it possible to observe a functional scoliosis in the process of conversion into a structural one The causes of an organic compensatory curve in structural scoliosis are not definitely known compound structural curvatures have been seen

curvature The motion of the spine in any one direction is a composite one, the sum of the motions of the individual vertebrae in that direction. Motion in the spine is facilitated by the elasticity of the intervertebral disks and the position and direction of the intervertebral articulations.

The motion in the different sections of the spine depends upon the conformation of the vertebrae in those sections as well as upon the position, shape and structure of the adjacent tissues. Motion between any two vertebrae is limited either by their bony contact or by their muscular or ligamentous attachment

One of the chief functions of the spine is to maintain the body in the erect posture The complex mechanism by which this is accomplished is not clear apparently it is an instinctive sense of balance which so coordinates the action of the muscles that the center of gravity is maintained over the central support of the spine—the sacrum In standing and walking the body is hardly ever in exactly the same posture for any length of time, every change of posture involving deviation of one part of the spine in one direction and of another part in another direction According to Lovett the sense of balance includes two instinctive factors (*1*) The erect person always strives to hold his head approximately over the middle of the pelvis in an anteroposterior median plane (*2*) He aims to hold the shoulder and pelvic girdles in the same frontal plane

In the anatomic position the maintenance of the erect posture is facilitated by the position of the bodies of the vertebrae in a vertical anteroposterior plane going through the base of the sacrum. When the lumbar vertebrae are displaced to the left because of a shortened left leg or by elevation of the right side of the pelvis a compensatory curve in the opposite direction is established in the dorsal region (Fig 19 A–B) Such a curve results from the response of the muscles to the sense of balance and equilibrium and allows the individual, when in the erect position to keep the weight and center of gravity over the base of support This formation of compensatory curves is an important activity of the spine and the muscles. In scoliosis the mechanism of compensatory curves possibly involves some as yet undiscovered factors What for instance governs the degree and extent of compensatory curves? Or why does one find in some cases of scoliosis that the primary and the compensatory curves are practically equal, while in others one is much longer than the other?

The curve of the spine in response to changed mechanics, as for example during walking standing on one leg or carrying a weight is physiologic Such a curve *is functional—a functional scoliosis which the individual* can readily correct It is also physiologic for a compensatory curve to form so that the individual can hold his head erect and keep the center of weight more or less in line with the normal center of gravity These changes occur

the reduction caused by the deformity itself (2) Knowledge of the scoliotic patient's vital capacity is important when there is resort to surgery, ade-

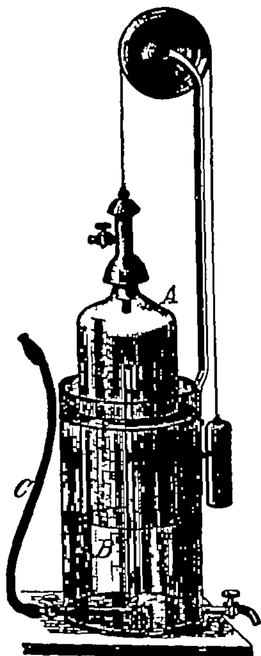


FIG 20 Spirometer (46)

quate precautions can then be taken both during and after operation to keep the lungs well aerated

In an analysis of 100 cases of scoliosis (30) it was found that the vital capacity varied from 53 per cent of normal in severe cases to 98 per cent

at birth and Lovett (62) doubts that "every case of organic double curve has first been a single postural one."

The spine, the ribs, the muscles of the back, and the paravertebral tissues are so intimately related that they are are interdependent. For example, when the spine deviates to the right, the intrathoracic organs become deflected to the right When some of the muscles of the back are paralyzed or paretic, the unopposed muscles contract and approximate the ends of the spine segment which they span, this results in a lateral deviation of the spine If the left pleura is the site of an empyema and the left paravertebral tissues become contracted, a right dorsal scoliosis develops Or, when the proximal segments of six or seven ribs are removed as in a thoracoplasty, a scoliosis with the convexity on the operated side may appear

Of particular significance is the interdependence of the ribs and the dorsal vertebrae, when these vertebrae move sideways or in a rotary direction they carry with them the corresponding ribs vice versa, a change in the position of the ribs influences the position of the vertebrae Much of the corrective therapy of scoliosis is based upon the knowledge of this mechanism

The complex mechanics of the spine and the mechanism of scoliosis involve many tissues and a variety of forces. The latter include traction as in respiration and compression, as in weight bearing Perhaps the prime factor is the little-understood sense of balance and equilibrium which is responsible for maintenance of the erect posture Much of what has been written about the mechanics of the spine is speculation For the time being we must content ourselves with a few simple facts, and trust to the future for ampler knowledge and a better understanding of this problem.

Vital Capacity

Vital capacity or the amount of air a person can forcibly expire after a full inspiration is a test of pulmonary function. Any disease or deformity which reduces the excursions of the chest reduces the vital capacity Obviously then in every case of structural scoliosis the vital capacity is reduced in direct proportion to the degree of the deformity In advanced and severe cases, in which there is marked distortion of the thorax with a corresponding decrease in pulmonary aeration the whole body is affected by the diminished intake of oxygen This is particularly true in kyphoscoliosis and razor back deformities in which atelectasis and complete loss of aeration of part of a lung may occur

Consideration of vital capacity is especially important in two circumstances (*1*) When corrective plaster jackets are used in treatment the jacket by causing discomfort and by physically restricting the expansion of one or another part of the chest may reduce the vital capacity beyond

CHAPTER III

CLASSIFICATION AND PATHOLOGY

Scoliosis is divided into two types—functional and structural—each clearly distinct from the other While their primary differences are pathologic, they also differ in etiology prognosis, and especially in the results of treatment Functional scoliosis is curable, structural scoliosis is not

The subject under discussion must not be confused with so-called sciatic scoliosis, which refers to a syndrome of low backache with or without sciatica Sciatic scoliosis is characterized by a marked flattening of the back and lateral tilt of the trunk with slight rotation of the lumbar vertebrae The tilt of the body is due to an instinctive effort to relieve pain, it corrects itself when the backache grows less or disappears

TERMINOLOGY

Although the pathologic processes in scoliosis affect all of the tissues of the trunk the spine is the most conspicuously involved, and the changes in it are fairly representative of those in the other structures Hence while the descriptive terms employed refer only to the spine they indicate also the changes in the back, the ribs, and the internal organs of the thorax and abdomen

Four essential features are included in the description of a scoliosis (*1*) direction of the spinal deviation from the midline (*2*) portion of the spine involved, (*3*) degree of deformity, (*4*) etiology

"Right and "left' indicates the direction in which the spine deviates from the midline Curves are further described as "cervical' "dorsal', or 'lumbar' according to the segment of the spine involved Thus a right dorsal curve is one which involves only the dorsal section of the spine and the convexity of which is toward the right, a left lumbar curve is one in which the lumbar vertebrae are displaced to the left of the midline The term right dorsal curve indicates that dorsal vertebrae only are displaced but does not necessarily imply that *all* the dorsal vertebrae are involved all of them may be displaced or only the upper or lower vertebrae may be affected the others remaining more or less undisturbed When more than one region is involved in a curve the respective parts of the spine are included in the term as for example a right or left cervicodorsal dorsolumbar or lumbosacral curve

When the entire or almost the entire spine deviates to one side the term total curve may be used C or simple curves are other terms for these single curves or deviations of the spine in one direction A double

in mild cases A plaster-of Paris jacket, by limiting the movements of the diaphragm and thorax reduced the vital capacity by 14 per cent, on an average

The vital-capacity test therefore, is an index of the degree of interference with normal respiration A plaster-of Paris jacket because it deliberately presses upon and reduces the excursions of one part of the chest or one side of the thorax is often used for the correction of a scoliosis One must therefore allow for greater movement and expansion of the opposite side of the thorax in order not to reduce too severely the vital capacity or aeration of the lungs. If the patient is conscious application of too tight a jacket will evoke a prompt complaint and an immediate correction But when the patient is under anesthesia the physician must make certain that the jacket is not too snug and will not interfere with adequate respiration.

Vital capacity is easily tested by the spirometer (Fig 20) an instrument which Howell (40) describes as follows

It consists of a graduated cylinder (*A*) and a receiver (*B*) filled with water The cylinder *A* is counterbalanced by a weight (*g*) so as to move up and down in the water of *B* with the least possible resistance The tube *C* passes through the wall of *B* and ends in the interior of *A* above the level of the water The free end of this tube is connected with the mouth or nose. When one breathes through this tube the expired air passes into *A* which rises from the water to receive it If *A* is graduated the amount of air breathed out may be measured directly An average figure for an adult man is placed at 3700 c.c but this will vary naturally with the size of the individual

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Terminology

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curve as a right dorsal left lumbar, is sometimes spoken of as an S or compound curve As a matter of convenience and for the sake of uniformity in describing a compound curve the upper curve is mentioned first, as for example right dorsal left lumbar or left cervical right dorsal left dorsolumbar curve The only exception to this is the occasional case in which one can be certain of the order in which the component parts of the curve appeared The part of the curve appearing first is the "primary" curve the other part is the "secondary" curve if the primary curve is a left lumbar curve and the secondary curve is a right dorsal the curve would be termed a left lumbar right dorsal curve In the majority of the compound curves one part is usually much more extensive than the other and is so evidently the part to be treated that it is referred to as the predominating or dominant curve.

The Special Scoliosis Committee of the American Orthopaedic Association appointed about twenty-five years ago proposed three grades of scoliotic deformity namely mild moderate and severe There is, of course no sharp line of demarcation between the various grades. As the severity of scoliosis is usually proportionate to the degree of rotation of the vertebrae, a slight rotation of the vertebrae and angulation of the ribs is considered a mild scoliosis more marked deformity of the vertebrae and ribs is termed a moderate scoliosis and extreme rotation of the vertebrae, with the resultant extreme angulation of the ribs is spoken of as a severe scoliosis.

When as is occasionally the case the cause of the scoliosis is discernible, e.g poliomyelitis, rickets, or congenital lesions, appropriate adjectives are used to indicate the etiology In cases of unknown etiology the scoliosis is designated as idiopathic this applies to the majority of cases.

By using the terms indicated, a given scoliosis can be described with fair accuracy as for example moderate paralytic right dorsolumbar curve or severe rachitic right dorsal left lumbar curve or mild congenital right dorsal curve In the first example the deformity is a complication of poliomyelitis the dorsal and lumbar vertebrae are displaced to the right forming one curve and the deformity is moderate in degree. In the second case, the deformity is severe in character is in a patient with other manifestations of rickets and the curve is a double one the upper segment involves the dorsal vertebrae which are displaced to the right of the mid line the lower part of the curve is in the lumbar region, and the vertebrae are displaced to the left of the midline In the third example the deformity is mild in degree is judged congenital because of the presence of a congenital vertebral lesion the dorsal vertebrae only are affected and the displacement is to the right of the midline.

Functional Scoliosis

Functional scoliosis is characterized by an asymmetric position of the trunk and back which vanishes on traction, stooping and recumbency, and which the patient can correct voluntarily It is commonly accompanied by other signs of faulty and relaxed posture, such as round shoulders, prominent abdomen, and flat feet It occurs with equal frequency in boys and girls and is said to be present in a large percentage of all school children Functional scoliosis is a physiologic posture which can be assumed by any normal child or adult it is pathologic only when it becomes habitual.

The commonest variety is a mild left dorsolumbar scoliosis (Fig 21),



Fig 21 Functional left dorsolumbar scoliosis

and according to Lovett (62) occurs in 90 per cent of the cases. Seen from the back a child with such a condition shows the following (*1*) The dorsal and lumbar segments of the spine deviate in a single or C curve to the left (*2*) The left shoulder is higher than the right (*3*) The left shoulder is carried forward and the right shoulder backward, as a result of torsion of the shoulder girdle (*4*) The waistline on the right side is curved in or exaggerated (*5*) The right iliac crest is more prominent than the left (*6*) The chest is shifted to the left in relation to the pelvis. (*7*) The left side of chest and back is more prominent than the right

In a forward bent position the right side of the upper back may be higher than the left as a result of a compensatory right cervicodorsal curve with rotation of the upper dorsal vertebrae to the right, while at the dorsolumbar junction the left side is more prominent than the right

My clinical experience does not bear out Lovett's statement that in

functional scoliosis the vertebral rotation is toward the concave side of the curve I have found that the rotation in all scolioses, including the functional, is always toward the convex side of the curve. When a patient with a functional left dorsolumbar scoliosis bends forward and the curve persists, it is the left side of the back which is the more prominent. The right side of the back at the cervicodorsal junction may be more conspicuous than the left when there is a noticeable compensatory upper dorsal or cervicodorsal curve. Naturally, in a functional right scoliosis the findings are reversed The vertebral deviation in a functional scoliosis is always mild and no structural changes are to be found in any vertebrae The two pathognomonic and diagnostic features in a functional scoliosis are (*1*) mild asymmetry of the back and lateral deviation of the spine, (*2*) ability to correct voluntarily the deviation of the trunk and to assume a normal symmetric posture.

Pathology

The only recognizable pathologic feature of functional scoliosis is its tendency to recur or be habitual None of the tissues of the back chest or abdomen show evidence of any gross structural changes none, that is to say that have ever been identified as causally related to or a sequel of functional scoliosis However one is justified in assuming the probable existence of a constitutional defect in the muscles, the ligaments or the alignment attachment, nutrition or structure of the bones. Such a deficiency explains why for instance some individuals naturally sit and stand erectly while others tend to slouch and slump, whether sitting standing or walking

Transitional Scoliosis

Most scolioses start between the sixth and tenth years of life Many of the nonidiopathic acquired scolioses begin as simple deviations of the spine from the midline as a result of some competent cause During the period when the scoliosis consists of a continuous or intermittent mild rotary lateral displacement of the vertebrae without structural changes the spine is in a state of transition and the scoliosis is transitional between the functional and organic types Theoretically the transitional scolioses should equal in number the structural variety Were we to see every case of scoliosis at the very beginning there is no doubt that such might be the case in practice, however very many more structural scolioses are seen than transitional ones

The diagnostic criteria of a transitional scoliosis may be listed as follows (*1*) Patient between 6 and 10 years of age (*2*) Persistent presence of functional scoliosis (*3*) Appearance of scoliosis in upright position al

though absent in recumbent position (4) Presence of S curve of the spine, be it ever so mild (5) Presence of an uncompensated congenital osseous anomaly of the vertebrae or ribs, causing a manifest disturbance of the symmetry of the spinal column (6) Familial history of structural scoliosis in patient with mild scoliosis in upright position (7) History of poliomyelitis in patient (8) Presence of fixed obliquity of the pelvis, whatever the cause

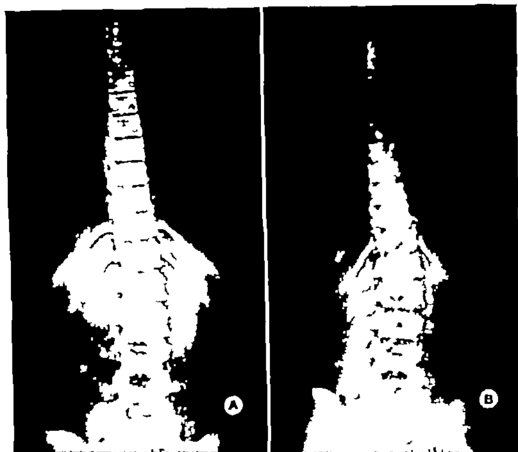


FIG 22 Transitional right lumbar scoliosis A Patient in recumbent position B Patient in upright position

The following case histories are examples of transitional scoliosis.

Case 1 In 1939 a 13-month old child was brought to me for a congenital subluxation of the left hip Plaster spicas in abduction led to an excellent recovery In 1944 roentgenograms showed the hips to be normal and symmetric On June 1 1940 the girl now 11 years old was brought to me again with the complaint of pain in the region of the left iliac crest of one week s duration The hips were normal In the recumbent position a mild right lumbar curve was found with deviation and rotation of the lumbar vertebrae (Fig 22A) in the upright position the curve was also to the right but more marked and involving the lower six dorsal as well as the lumbar vertebrae with deviation and rotation of the vertebrae (Fig 22B) No cause for the scoliosis was revealed by the physical examination not only were the hips normal but

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1, to a left dorsal, right dorsolumbar curve 1, to a left dorsal curve, 1, to a right dorsal curve, and 1, to a left dorsal right lumbar curve

The above figures demonstrate more than anything else the impossibility of predicting the type of structural scoliosis which may result from a functional curve A guiding principle in the treatment of scoliosis must be

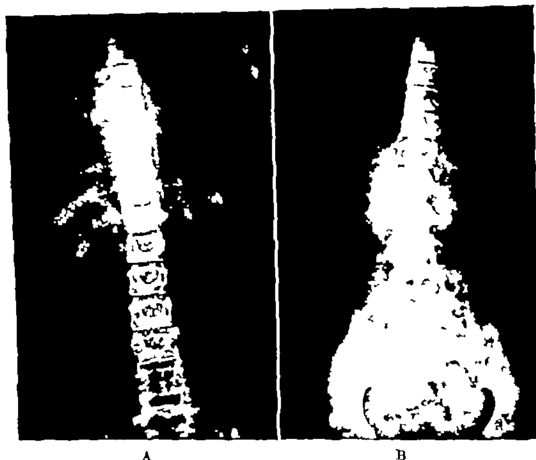


FIG 23 Transitional scoliosis A Patient in recumbent position no scoliosis B Patient in upright position left lumbar scoliosis

that every functional curvature is a potential structural one, and is to be treated accordingly

At this point one is faced with a sort of impasse in what might be assumed to be the natural evolution of a scoliosis. For, since 90 per cent of the functional scolioses are left dorsolumbar ones, one might reasonably expect the transition to result in a like percentage of right dorsal left lumbar curves. But, as the figures of the series cited above show a left dorsolumbar functional curvature can become any one of a large variety of structural scolioses Lovett's (62) explanation that the adjustment from a functional to the structural scoliosis "will naturally occur where the

there was neither manifest muscle imbalance nor any disparity in the length of the legs

It is obvious that the scoliosis just described was in a state of transition Despite the deviation and rotation of the vertebrae, gross wedging or evidence of internal structural changes was absent A half inch lift under the right leg has resulted in the disappearance of the scoliosis, but whether permanently or not remains to be seen Possibly, continued active attention will prevent recurrence or the X factor (*see* Etiology) will continue to operate structural changes will take place and the scoliosis will become a fixed and organic deformity

Case 2 I first saw this 9-year-old girl on September 16 1948 She was the child of a physician and had been carefully watched since birth Soon after a high forceps delivery a mild left spastic hemiplegia was noticed The left arm improved rapidly but the spastic left equinus persisted The left Achilles tendon was lengthened when the child was 4 years old and led to a temporary improvement in her gait When she was brought to me for spasticity of the left leg a complete physical examination revealed the presence of a mild left scoliosis In the recumbent position the spine was in the midline In the standing position the spine deviated mildly to the left The curve began at the level of the fourth dorsal vertebra and ended in the midlumbar region, with the apex at the ninth dorsal vertebra. The left scapula was slightly prominent In the forward bent position the back was asymmetric to a slight degree the ribs on the left side being more prominent than those on the right The right shoulder was higher than the left (indicating the beginning of a compensatory curve in the right cervicodorsal area) Roentgenograms made it evident that the vertebral column was in the midline in the recumbent position but fell into a right dorsal curve in the upright position. The child was fitted with a celluloid corset and a roentgenogram proved that the corset was maintaining the spine in the midline Roentgenograms in June 1949 with the corset off showed the spine in the midline in the recumbent position and a mild left lumbar curve in the upright position (Fig 23A B)

This is a case of an unstable spine, caused perhaps by a disturbed musculature as a result of the spastic hemiplegia No structural changes in the vertebrae are visible as yet and the scoliosis is in a transitional stage

Judging from personal experience I venture the statement that only a small fraction of functional scolioses are transformed into organic ones Figures in the literature vary widely 2 to 3 per cent in one instance (76) to 26 out of 86 in another (62)

The breakdown of these 26 cases is interesting These are Hess s statistics quoted by Lovett (62) Of 21 cases of *left total scoliosis* 7 changed to right dorsal and left dorsolumbar scoliosis 4, to left lumbar curves, with 2 right dorsal scolioses 3 to left dorsal curves 2 to left dorsal right dorsolumbar curves 2 to right dorsal curves 1 to left dorsal right dorsolumbar curve and 1 showed slight compensating curves In 5 cases of *right total scoliosis* 1 changed to a right dorsal left dorsolumbar curve

scoliotic curves the simple and the compound Close study, however, will reveal a compensatory curve even in the simple curve, usually short and either above or below, or both above and below, the major curve

Simple Curves

Dorsal Curve Some or all of the dorsal vertebrae are involved in this type of curve which may vary from the mildest to the severest degree.

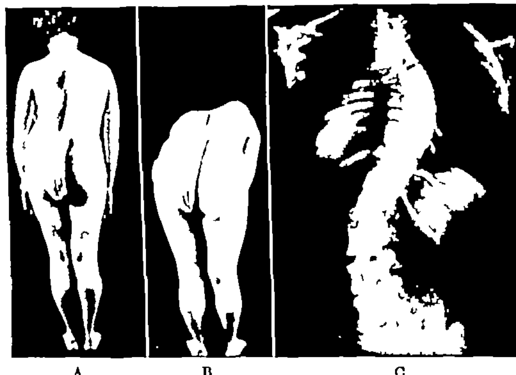


FIG 25 Moderate right dorsal scoliosis A Patient in upright position B Patient in forward bent position C Roentgenogram of spine

Usually there is a slight compensatory curve in the opposite direction, which includes only a few vertebrae and does not affect materially either the character of the major curve or its treatment. In this type of curve, the deformity is practically limited to the chest while the lumbar region and the pelvis are only rarely and slightly if at all affected

Figure 25 illustrates a moderate right dorsal curve The posterior view of the patient shows the following asymmetry of the back, right shoulder higher than the left right scapula elevated and rotated so that its inferior angle projects and is much farther from the midline than that of the left scapula deviation of the spine to the right with the apex of the curve at about the seventh or eighth dorsal vertebra, the ribs on the right side are prominent project backward and their angulation is more marked

spine offers the least resistance to it, and as individual vertebral columns vary the compensatory adjustment will take various forms, only serves to emphasize the fact that the transition from a normal back or from functional scoliosis to a structural one is still a problem that needs solving

Structural Scoliosis

The picture presented by a patient with a structural or rigid scoliosis differs completely from one with a functional type In the average case



A B

Fig 24 Mild dorsal curve. A Patient in upright position B Roentgenogram of spine

(Fig 24A B) the trunk is misshapen the spine deviates from the midline in one or more areas one iliac crest is more prominent than the other the ribs on one side project backward and the chest is asymmetric to a varying degree No matter what position the patient is in the deformity remains he cannot assume a normal position he cannot voluntarily correct the distortion of his body The deformity is fixed because of structural changes in the vertebrae ribs ligaments, and related parts of the trunk

Structural scoliosis varies from the mildest type in which the deformity may appear to be merely a simple postural curve to the severest degree in which the ribs are so distorted and sharply angulated that they create the so-called razor back.

As explained at the beginning of this chapter there are two types of

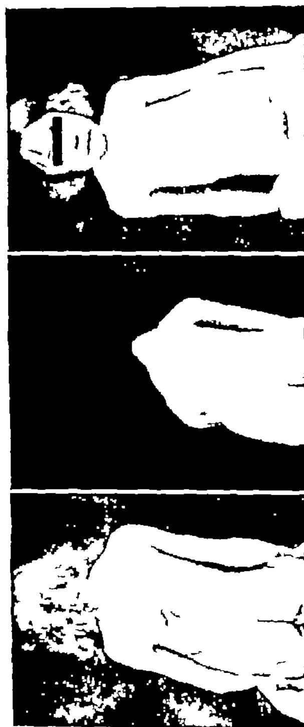


FIG 27 Severe *right dorsal razor back scoliosis* A Patient in upright position B Patient in forward bent position C Patient in upright position front view

than in a mild case, the downward inclination of the ribs is increased and the intercostal spaces are wider than normal

Figures 26 27 and 28 illustrate severe forms of right dorsal scoliosis, in which the angulation may be so marked that the proximal ends of the ribs form a sharp ridge beginning opposite the spine of the scapula and running downward and outward the entire length of the chest In the severest cases, the backward projection of the right ribs may be so marked

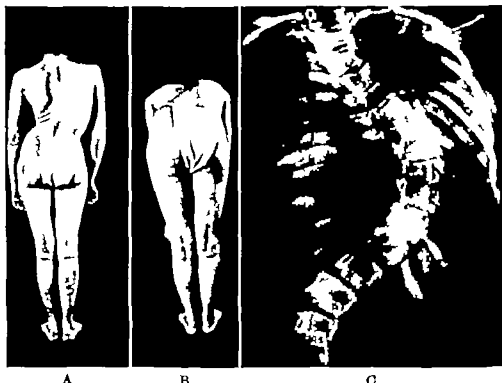


FIG 26 Severe right dorsal scoliosis A, Patient in upright position B Patient in forward bent position C Roentgenogram of spine

that it is rather difficult to palpate and define the spinous processes the right arm hangs away from the body and is farther from the midline than the left arm on the right side a transverse furrow or crease is usually present at the junction of the chest and lumbar region and the normal contour of the waistline is entirely obliterated or much reduced. Seen from the back, the left shoulder is lower than the right and somewhat posterior to it the left scapula is less conspicuous and is lower than the right, and its inferior angle is much nearer the midline that that of the right The left side of the chest is flattened below the scapula there is a groove or crease more or less marked running from the spine downward and outward. By raising the left arm, the flattening or actual hollowing of

horizontal, the intercostal spaces are reduced, especially at the deepest part of the hollow (Fig 27D), the waistline is almost without exception exaggerated, and the iliac crest is markedly prominent



Fig 28 Dorsal scoliosis showing the different elements of deformity (*A* wedging *B* eccentric position of spinous process *C* asymmetry of articular facets)

the left side of the chest can be seen even more clearly, the deepest part of the hollow which is sometimes so deep that a fist can be inserted in it,



FIG. 27 Continued—D Roentgenogram of spine showing typical question mark deformity

is opposite the summit of the convexity on the right side. The left ribs are flattened and close together their downward inclination may be so much reduced that the sixth seventh, and eighth ribs are practically

rhomboidal, lozenge-shaped, or transitional vertebrae. Throughout the greater part of the curve the shadows of the spinous processes are to the left of the middle of the bodies The shadows of the right costal facets circular or oval areas, lighter than the rest of the body, are larger than those of the left side, indicating that the right facets present a larger surface to view than the left costal facets The position of the spinous processes and the appearance of the facets indicate a rotation of the vertebrae to the right (Fig 28) When the rotation is extreme the left costal facets may not be seen at all A stereoroentgenogram visualizes the vertebral rotation even more clearly On the right side there is an increased downward inclination of the ribs, and the intercostal spaces are wider than normal On the left side the ribs are crowded together some of them actually touching and the intercostal spaces are diminished The heart may appear displaced to the left because of the spinal curve to the right The appearance of the pelvis is normal and symmetric, except when some associated condition such as a unilateral dislocation of a hip or poliomyelitis involving the trunk and lower limbs causes a deformity

Wedge Vertebrae The transverse diameters of these vertebrae (Fig 29) are increased the perpendicular diameters are increased on the convex side and diminished on the concave The pedicles and laminas are smaller on the concave than on the convex side The spinous processes while shifted from the midline of the back to the convex side of the curvature may be and often are turned toward the concavity of the curve. The vertebral or spinal foramen is irregularly triangular or ovoid, with the narrow part on the side of the concavity The internal structure of the vertebral bodies is greatly altered The lamellas on the side of the concavity are short thick numerous and closely placed the bone resembles compact bone thus being adapted to bear increased strain On the convex side the lamellas are long thin sparse, widely separated and irregularly distributed the bone is porous. In the severest cases the wedge vertebrae may be so displaced and rotated that their horizontal surfaces are in a vertical plane and the tips of the spinous processes, as previously mentioned may actually point to the side of the concavity

Transitional Vertebrae The changes in these vertebrae (Fig 29) are characterized by a lateral displacement and twisting of the superior and inferior surfaces, so that the vertical and horizontal surfaces join at acute and obtuse angles. In some cases the bodies of these vertebrae as of any of the others may be fused over an area of several vertebrae The transverse processes suffer less change than other parts of the vertebrae

Intervertebral Disks Conforming to the changes in their respective vertebrae the involved disks are markedly changed in shape and structure Their symmetry disappears the vertical diameter is diminished on the

In the forward-bent position with the arms hanging down it becomes even clearer that it is the chest which is chiefly involved On the right side there is an upward projection of the ribs, indicating angulation of the ribs and rotation of the vertebrae, while on the left side the chest is flat or hollow The asymmetry of the back is most evident in this position, and the projection or angulation of the ribs is seen to best advantage

Even in the mildest cases, the forward bent position will demonstrate the asymmetry of the back by the rotation of the vertebrae on one side as evidenced by the increased projection of the ribs. For this reason no examination of a case of scoliosis is complete without seeing the conformation of the back in a forward bent position Deviation of the spine is best observed in the upright position rotation deformity is seen most clearly in the forward bent position In contrast the lumbar region is equally flat on both sides

A front view in a dorsal scoliosis shows asymmetry of the chest the right side is flattened and the left side is prominent and projecting if the patient is a girl with well-developed breasts the left breast will be more prominent than the right and will appear larger (This often leads parents to believe that the breasts are unequally developed not infrequently, in mild or moderate cases the prominence of one breast is the first sign noticed by the parents) The left ribs, especially the lower ones, are much more convex forward than normally the left lower costal border is prominent and sometimes everted The sternum is practically in the midline as a rule suffering little displacement however it is often rotated on a vertical axis, so that its left border projects farther forward than the right thus conforming to and being part of the increased convexity of the left side of the chest As in the posterior view the left shoulder is lower than the right the waistline on the left is exaggerated and the left iliac crest is prominent the pelvis is unaffected and the anterior superior iliac spines are on the same horizontal level

In very advanced cases, there is considerable shortening of the patient's height The lower ribs may be very close to touching or even below the iliac crests the chest in other words, is telescoped into the pelvis, and the abdominal organs are crowded together

An anteroposterior roentgenogram of a dorsal curve reveals that the spine is shaped very much like a question mark (Fig 27D) The curve is more or less limited to the dorsal region and the lumbar vertebrae form the perpendicular end of the question mark Two or three of the vertebrae at the apex of the curve are wedge-shaped with the base of the wedge on the right side As the cervical and lumbar parts are approached the bodies of the vertebrae grow more nearly normal in shape i e rectangular These vertebrae which are near the ends of the curve are called oblique

Sternum This part of the chest is the most rigidly fixed, and suffers the least deformation (Fig 31), even in severe scoliosis The following

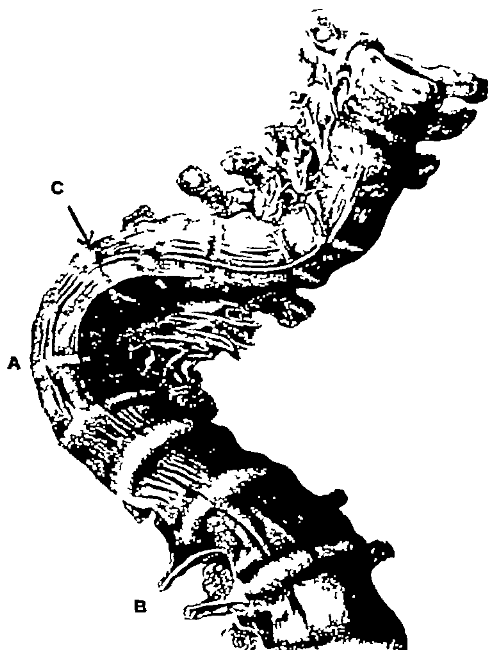


FIG 30 Segment of scoliotic spine (72) (*A* wedge vertebra *B* transitional vertebra *C* anterior longitudinal ligament)

variations in position may occur (*1*) A lateral displacement (*2*) Obliquity of the lower end turned either to the convex or concave side of the lateral curve A study by Fauconnet (25) of the sternum in a series of patients with the same type of scoliosis showed about an equal number turned to

concave side and increased on the convex, the pulpy central structure is displaced to the convex side



Fig 29 Scoliotic spine showing wedge and transitional vertebrae (*A* wedge vertebrae *B* transitional vertebrae)

Ligaments. In adaptation to the changes in the bones which they unite, the ligaments alter (Fig 30) On the concave side where the bones are crowded together all the ligaments are shorter and thicker than normal on the convex side they are longer and thinner than normal

vertebrae and to backward projection of the bodies and transverse processes The left lumbar region is resistant to touch, in contrast to the right side which is soft and yielding Because of the absence of ribs in the lumbar region, rotation is neither as marked nor as evident as in similar deformities of the thoracic region

Inequality of the lower limbs may be found in this type of curvature the limb on the convex side of the curve being a half inch to an inch shorter than the other limb *Patients with simple lumbar curves as a rule seek*

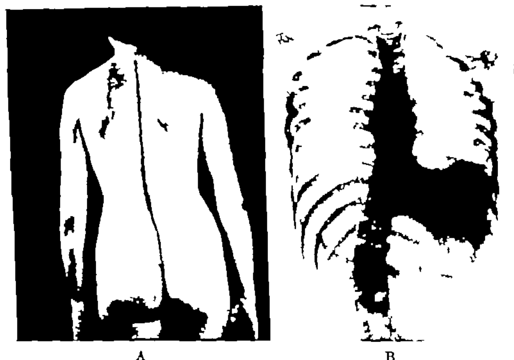


Fig 32 Left lumbar scoliosis A Patient in upright position with line of spine emphasized B Roentgenogram of spine

advice not because of a deformity of the back but for a supposedly shortened leg or a high 'hip'

In the forward bent position the back is symmetric in the upper part, in the lumbar region there is an upward projection on the left side and a flatness or hollowness on the right

Unlike the vertebrae in a dorsal curve where the backward projection of the ribs is more or less proportionate to and indicative of the degree of the rotation of the vertebrae the lumbar vertebrae are much more rotated than the external appearance of the back indicates Not infrequently, a slight compensatory curve to the right may be seen in the lower dorsal region and occasionally the spinous processes of the sacrum form a convex line to the right indicating a compensatory curve in the sacrum

the right and to the left (3) Rotation around its longitudinal axis causing one lateral border (commonly the one toward the concavity of the lateral curve) to become more prominent Occasionally in cases of severest deformity the sternum is projected forward so that the anteroposterior diameter of the chest is increased

Lumbar Curve In this type of curve (Figs. 32 and 33) the deformity involves the lumbar region and the iliac crests while the chest



FIG 31 Roentgenogram showing position of sternum the outline of which has been emphasized

and shoulders remain practically normal The curve resembles an inverted question mark The lumbar vertebrae are compromised the apex of the curve being at about the third lumbar vertebra The twelfth and even the eleventh dorsal vertebrae occasionally form part of the curve In a left lumbar curve posteriorly the most noticeable feature is a prominence of the right iliac crest The waistline on the right is exaggerated on the left it is obliterated, the lateral boundary of the thoracic and lumbar regions forming a straight line Clinically the curve to the left of the lumbar segment of the spine is demonstrated by the visible and palpable deviation of the spinous processes The left side of the lumbar area projects backward its prominence being due to rotation of the lumbar

Anteriorly, the anterior superior iliac spines are in the same horizontal plane if the scoliosis is idiopathic but if there is associated muscle weakness or imbalance, for whatever reason the anterior superior iliac spine on the side of the convexity may be lower than that of the other side

The lateral deviation of the lumbar section of the spine is clearly evident in an anteroposterior roentgenogram (Figs 32B and 33) The spinous processes of the lumbar vertebrae which are normally in the middle of the bodies will be seen to the right of this position or even at the right border of the bodies The right articular processes as a rule cannot be seen at all the left articular processes are visible to the right of the left border of the bodies or even over their middle indicating rotation of the lumbar vertebrae to the left The intervertebral spaces and disks are asymmetric their vertical diameter being much larger on the left side than on the right, especially at the apex of the curve At the lumbosacral junction the last lumbar vertebra is tilted downward on the left side and upward on the right, and the articular processes on the left are smaller or appear smaller than those on the right The sacrum is usually not involved, but in some cases it is part of the lumbar curve or it forms a compensatory curve to the right with structural distortion. The pelvis may be entirely normal, or occasionally, asymmetric as a result of such conditions as poliomyelitis, syringomyelia or congenital hip dysplasia, in such cases there is an unequal weight bearing on the pelvis with rotational or torsional changes

The limitation of motion in a simple left lumbar curve depends on the severity of the curve. Usually bending to the left side is the only motion which is diminished appreciably

Obviously the conditions described above are reversed in the case of a right lumbar scoliosis

Dorsolumbar Curve This is the most common of the simple curves involving more than one segment of the spine namely cervicodorsal dorsolumbar and lumbosacral The curve is continuous from about the third or fourth dorsal to the third fourth or fifth lumbar vertebra. Generally the deviation is somewhat greater than the degree of abnormal rotation

Posteriorly in a right dorsolumbar curve the body is shifted to the right (Figs 34 and 35) if a line were to be drawn straight upward from the fold between the buttocks the dorsal and lumbar regions and even at times the head would show a marked list to the right of that line The right shoulder is higher than the left The right scapula is elevated and rotated its inferior angle is prominent and it is farther from the midline than the left scapula. Beginning at the spine a furrow extends downward and outward below the left scapula On the right the back projects backward

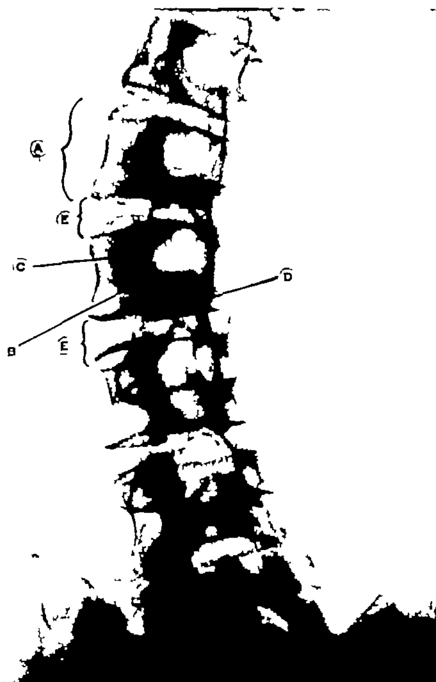


FIG 33 Left lumbar curve showing changes in position and structure of vertebrae right articular processes are not visible indicating rotation of vertebrae to the left (*A* wedge vertebra *B* left articular process *C* left articular facet *D* spinous process *E* intervertebral disks bigger on left than on right side)

the right arm hangs farther away from the side, the waistline is obliterated, and the hip is flat On the left, the arm hangs closer to the side, the waist line is exaggerated, and iliac crest is prominent, and the chest is flat or hollow The downward inclination of the ribs is increased on the right diminished on the left, the intercostal spaces are widened on the right, narrowed on the left In the lumbar region, the right side is somewhat more prominent than the left



FIG 35 Severe right dorsolumbar curve A Patient in upright position B Patient in forward bent position C Roentgenogram of spine

In the forward bent position (Figs 34B and 35B) the back is asymmetric with the right side convex due to the upward projection of the ribs and the left side flat or concave In the axillary region, flattening of the ribs compresses the right side of the chest

Anteriorly the deformity is equally marked. The trunk deviates to the right the right shoulder is higher, the right side of the chest is flattened the lower ribs on the right may be close to, touching or below the iliac crests The left iliac crest is prominent the waistline on the left is markedly exaggerated the chest is convex and bulging (in girls with well-developed breasts the left breast appearing larger) In mild cases, the abdomen is not much affected in severe cases there may be considerable asymmetry the



Fig 34 Moderate right dorsolumbar curve A Patient in upright position B Patient in forward bent position C Roentgenogram of spine

the neck, chest, and shoulders (Fig 36), with the apex of the curve at or near the cervicodorsal junction

A posterior view of a left cervicodorsal curve (Fig 36) shows a marked prominence of the left side of the neck and chest On the left the neck appears much shorter than on the right, where the normal curve at the base is much exaggerated As a result of a compensatory curve in the upper cervical region, the head is inclined to the right The left shoulder is higher than the right The deformity of the chest is the same as in a dorsal curve The normal backward curve of the dorsal region is always markedly increased "kyphoscoliosis' is therefore a more correct term for these cases.

Roentgenographically the curve is seen to involve the lower cervical and the upper dorsal vertebrae and there is usually a marked rotation deformity

A right cervicodorsal curve will show the reverse changes from those just described

Compound Curves

In a compound curve some of the vertebrae deviate to one side of the midline while others are displaced to the opposite side These curves may be double triple or quadruple the most common being a double or S curve in which the dorsal region deviates in one direction and the lumbar in the other direction

Double Curve The type seen most frequently is the right dorsal left lumbar curve, a combination of the simple dorsal and lumbar curves The back of course presents the combined characteristics of the constituent dorsal and lumbar curves

The S of the double curve may be shaped in one of three ways In order of frequency of occurrence these are (*1*) The upper part of the S, the dorsal section, is long and is the predominant part the lumbar curve is short. (*2*) The S is regular in shape, both dorsal and lumbar sections being of equal length (*3*) The dorsal curve is short the lumbar portion long

Figure 37 is an example of the long right dorsal short left lumbar curve In this type the lower nine or ten dorsal vertebrae form a right convex curve with the apex at about the eighth or ninth vertebra the uppermost dorsal vertebrae are in the midline or curve slightly to the left The lumbar curve is extremely short with the apex between the third and fourth vertebrae

Posteriorly the trunk deviates to the right and the right shoulder and scapula are higher than the left The deformity of the chest is like that in a simple dorsal curve the ribs on the right side projecting backward while those on the left side are flattened. In the lumbar region, the left side is

lower part bulging and the vertical diameter much reduced The anterior superior iliac spinous processes are usually on the same level.

An anteroposterior roentgenogram reveals that the curve of the spine extends from the third or fourth dorsal to the third, fourth or fifth lumbar vertebra In almost every case the *upper* dorsal vertebrae curve slightly to the left The apex of the curve is at the dorsolumbar junction, or at the tenth or eleventh dorsal vertebra. The dorsal vertebrae have the same appearance as in simple dorsal curves Usually, the lumbar vertebrae are placed obliquely and are slightly rotated to the right The ribs have the same appearance as in dorsal curves. The pelvis is only occasionally af-



Fig 36 Left cervicodorsal kyphoscoliosis

fected the change consisting of a unilateral contraction especially in paralyzed individuals

The mobility of the spine is governed by the severity of the curvature. In the mild and moderate types there is considerable flexibility and the deformity can be reduced by suspension or manipulation lateral bending to the right is the only markedly restricted spinal motion. In severe cases, the dorsal portion of the spine is practically fixed and manual pressure will not cause reduction of the curve However flexion and extension in the lumbar region are fairly extensive even in the severest type since the lumbar vertebrae are less involved than the dorsal actually the lowest two lumbar vertebrae may not be changed at all.

In a left dorsolumbar curve the findings are the reverse of those just described

Cervicodorsal Curves These curves are usually severe except when caused by congenital malformation of the spine The deformity involves

lumbar curve begins at the first or second lumbar vertebra and terminates at the sacrum As a rule, the rotation is of moderate degree and never as marked as in curves in which all the lumbar vertebrae are involved The intervertebral spaces on the left are larger than those on the right, the articular and transverse processes are more clearly defined on the left than on the right the spinous processes are to the right of the middle of the vertebral bodies. The lumbosacral junction is usually symmetric the last lumbar vertebra being placed over the middle of the sacrum

Figure 38 is an example of a typical right dorsal left lumbar S curve in which the two sections of the curve are of practically equal length The dorsal curve begins at about the first dorsal vertebra and ends at about the tenth dorsal, with the apex of the curve at about the sixth dorsal The lumbar curve begins at about the eleventh or twelfth dorsal vertebra and ends at the sacrum, with the apex between the second and third lumbar

Clinically the posterior view shows the shoulders to be on the same level or the right slightly elevated, the right side of the chest is more prominent than the left, which is either flat or somewhat hollow the right scapula is somewhat more prominent and elevated than the left In this deformity the *right* iliac crest is prominent the result of the curve of the lumbar vertebrae to the left It is worth noting that deviation of the lumbar vertebrae always produces prominence of the iliac crest on the concave side of the curve The entire left side of the lumbar region bulges while the right side is flat or hollow

The anterior view of the patient shows a moderate flattening of the right side of the chest and a bulging of the left side The right iliac crest is prominent The trunk and head are in the midline In most cases the anterior superior iliac spines are on the same level in a few, the left is lower

The characteristic roentgenogram in this type of curvature shows (*1*) a compound curve the upper and lower parts of which are approximately equal (*2*) displacement to the right of the upper 9 or 10 dorsal vertebrae (*3*) deviation of the lumbar vertebrae to the left, (*4*) as a rule marked rotation of the lumbar vertebrae frequently as much as 90 degrees giving rise to the same roentgenographic features as in simple lumbar curves

This type of curve may begin in either the dorsal or lumbar region and is often spontaneously compensated In external appearance, particularly in the clothed individual this is the least conspicuous of the compound curves The chest is almost never severely deformed and acute angulation of the ribs is rare Nevertheless both in this type and in the short right dorsal long left lumbar curve the curvature of the lumbar region is so marked that the right iliac crest may be very prominent

more prominent than the right, the right iliac crest is prominent, the line of the spinous processes is convex to the left.

The forward bent position demonstrates clearly the asymmetry of the chest and the upward projection of the ribs on the right. In extreme flexion, the asymmetry of the lumbar region and the upward projection on the left become apparent

Seen from the front the trunk is markedly asymmetric, and may be inclined to the right On the right side the shoulder is raised, the chest is flattened on the left, the chest is bulging or convex (in patients with well

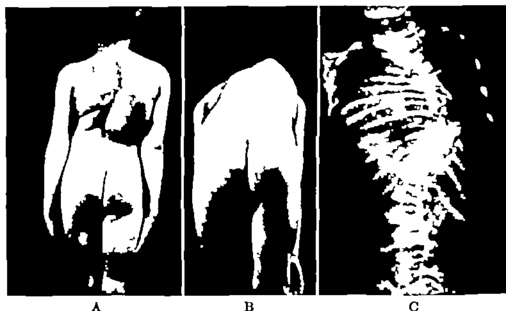


FIG 37 Long right dorsal short left lumbar scoliosis A Patient in upright position B Patient in forward bent position C Roentgenogram of spine

developed breasts, the left breast looks much larger than the right) The anterior superior iliac spines are on the same level.

The roentgenogram (Fig 37) shows the long upper or dorsal curve to the right and a shorter lower or lumbar curve to the left Usually the upper curve begins at the second or third dorsal vertebra and ends at the twelfth dorsal or first lumbar vertebra. The appearance of the dorsal vertebrae is the same as in simple dorsal curves. The spinous processes are to the left of the middle of the vertebral bodies and the right costal facets appear larger than the left indicating rotation of the vertebrae to the right At the apex of the curve the vertebrae are wedge shaped but at the dorsolumbar junction i e the twelfth dorsal or first or second lumbar vertebra, they may be quite normal On the right side the ribs are markedly separated and the intercostal spaces enlarged on the left, the ribs are close together and the intercostal spaces diminished The short sharp



Fig 39 Roentgenogram of spine with short right dorsal long left lumbar S curve

Figure 39 illustrates the third type of compound S curve—a short right dorsal long left lumbar curve The lumbar curve is the more prominent part of the deformity, and it usually shows a more advanced degree of



FIG 38 Roentgenogram of spine with typical right dorsal left lumbar S curve Dorsal and lumbar segments equal in extent

in the presacral (better termed "suprasacral") part of the spine (Fig 40) Although the sacrum often takes part in the compound curves described above being deflected in the opposite direction from the lumbar vertebrae and thus forming a third curve it is better to reserve the term "triple curve for those curvatures in which the three distinct curves are limited to the suprasacral vertebrae

In the curve under discussion the upper dorsal or cervicodorsal and the lumbar vertebrae curve in one direction while the middle and lower dorsal vertebrae form a curve in the opposite direction In rare instances, there is actually a quadruple curve, the cervical and lumbar segments being deflected to one side and the dorsal vertebrae and the sacrum curving to the opposite side

Table I gives the results of a study of 167 cases of structural scoliosis.

TABLE I

Types of Curve Found Among 167 Cases of Structural Scoliosis

Type of curve	Number of cases	Per cent of total
Right dorsal left lumbar	105	63
Right dorsolumbar	32	19+
Right dorsal	9	5+
Left dorsolumbar	8	5
Left dorsal	7	4+
Left dorsal right lumbar	4	2+
Left lumbar	2	1+

These figures are subject to wide variations dependent chiefly on individual interpretations of the curvature They do however indicate as shown in almost all statistics that there is a predominance of the right dorsal left lumbar and of the right dorsolumbar types of scoliosis

Lumbosacral Junction The flexible or suprasacral part of the spine is supported on the base of the sacrum at three points—the body and the articular processes. The sacrum thus serves as a tripod Obviously, should the body of the first sacral segment or either articular process become displaced or malformed the change in the foundation must disturb the balance of the spine and initiate a lateral and rotary displacement of the lumbar region

In one study (2) an anomalous condition of the first sacral segment, or of the fourth or fifth lumbar vertebra was found in 44 of 50 cases. Particular emphasis was laid on inequality of the lower lumbar and lumbosacral articular processes as a cause of scoliosis In a roentgenographic study of 50 unselected cases of scoliosis I found that in 17 there was an increase in the size of the articular processes of the fourth and fifth lumbar

rotation and deviation than the dorsal section The features are those of an exaggerated lumbar curve plus a mild deformity of the chest. The



Fig 40 Triple suprasacral curve

shoulders are on the same level, the right scapula slightly more prominent than the left

The roentgenogram reveals a marked lumbar or actually a dorsolumbar curve and a shorter and milder dorsal curve in the opposite direction

Triple Curve This infrequent deformity comprises three distinct curves

bar curve, and vary from a slight asymmetry to extreme deformity The most badly deformed pelves are found in severely paralyzed patients, who as a rule walk little if at all and maintain awkward sitting postures for



FIG 41 Roentgenogram of spine with right dorsolumbar curve roentgen ray tube centered over lower dorsal vertebrae Apparent asymmetry in lumbosacral area, left articular processes being larger than right

vertebrae and of the first sacral segments on the concave side of the lumbar curve, as compared to those on the convex side This is particularly apt to be the case when the lumbar vertebrae are involved in the major curve or in a primary curve In 12 cases the lumbosacral joint was in the mid line the articular and transverse processes being symmetric and equal in size, as shown on the roentgenograms Among the remaining 21 patients there were several cases of congenital malformations and several of rickets, in other words, cases in which the causes were evident In 4 patients the articular processes on the convex side of the curve appeared larger than those on the concave side In another case in which two roentgenograms were made of the same lumbosacral joint one showed unequal articular processes while in the other they were almost equal Roentgenograms of the spine that had been made with the tube centered over the lower dorsal vertebrae seemed in some cases to show unequal lumbosacral processes (Fig 41) while the articular processes were found to be equal in these cases when the roentgenograms were made with the rays focused directly over the lumbosacral joint (Fig 42) I gained the impression from this study that the inequality in the lower lumbar articular processes is not a constant change that it is often absent, and that it may even be the reverse of the usual We know furthermore, that a bone will alter in form and structure in adaptation to an altered function At the summit of a curve all the parts of the vertebrae change in conforming to the stresses imposed upon them The articular processes laminas and pedicles on the two sides of such a vertebra are unequal While present in all deformed vertebrae these changes are less marked at the ends of a curve It is possible therefore and even probable that as the lumbar curve develops and the vertebrae become displaced and deformed there is a secondary change in the articular and transverse processes of the last lumbar and first sacral vertebrae Admitting then that inequalities and asymmetries exist at the lumbosacral junction these cannot be considered as primary and causative of scoliosis in any but a very small number of cases. The reasons which lead me to this conclusion are (*1*) They do not occur in all cases (*2*) The changes in any given curve are not constant (*3*) They do not resemble congenital lesions elsewhere in the spine (*4*) In many cases, the lumbosacral joint is symmetric (*5*) They may be secondary developments, the result and not the cause of the scoliosis

Pelvis Pathologic disturbances in the pelvis are infrequent The two varieties that have been observed are a postural change an alteration in the angle of inclination of the pelvis as a whole including a torsion of one os innominatum in relation to the other (see Fig 10A–D) or a structural contraction or distortion of one or both sides (Fig 43)

Such changes occur in about 1 to 2 per cent of the patients with scoliosis. They have been found only as a concomitant of a fairly well marked lum

bar curve and vary from a slight asymmetry to extreme deformity The most badly deformed pelves are found in severely paralyzed patients who as a rule walk little if at all and maintain awkward sitting postures for



Fig 41 Roentgenogram of spine with right dorsolumbar curve roentgen ray tube centered over lower dorsal vertebrae Apparent asymmetry in lumbosacral area, left articular processes being larger than right



FIG 42. Roentgenogram of lumbosacral area of same spine as in Figure 41 cone view Note symmetry of articular processes of fifth lumbar vertebra

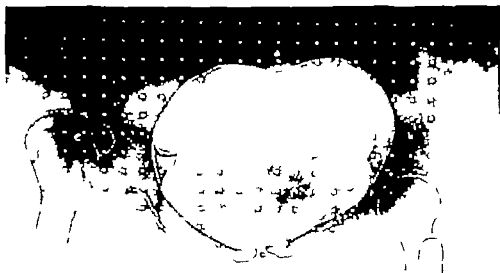
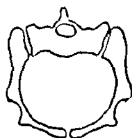


FIG 43 Contracted pelvis in severe paralytic scoliosis contraction of left side of pelvis is associated with left lumbosacral curve arrow marks anterior flattening of pelvic inlet on affected side (a sacrum c symphysis pubis e distorted upper extremity of right femur)

long periods. In such cases the bones suffer considerable atrophy as a result of disuse or the neurovascular changes induced by the poliomyelitis and easily yield to pressure and strain. When the pelvis is involved in the



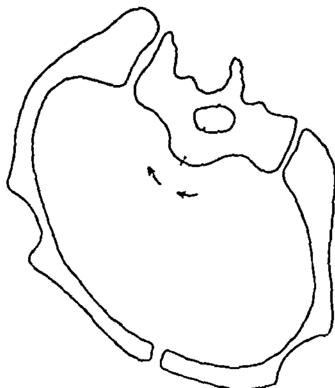


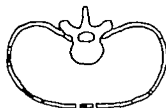
FIG 44 Cross section of pelvis in lumbosacral scoliosis (57) Inset Cross section of normal pelvis

scoliotic deformity its structural changes resemble those of the dorsal area (Fig 44)

As brought out in a study of the pelvis in paralyzed pregnant women (57) the pelvis may be tilted in one of four directions namely (1) a lateral tilt around a ventroposterior axis i e a lateral pelvic obliquity (Fig 10A) (2) an anterior tilt of both innominate bones around a transverse axis i.e a lumbar lordosis (Fig 10B) (3) rotation around a longitudinal axis i.e a ventroposterior axis deviation (Fig 10C) and (4) a torsion of one innominate bone upon the other around a common trans

verse axis i e, a torsional deformity (Fig 16D) The first three types of positional change are generally accepted, the authors of the study, however became convinced that the fourth type though infrequent also exists. Their opinion is based on the observation that in a few patients the anterior superior iliac spine on the affected side was on a lower level than its mate, while the iliac crests remained in the same plane

Roentgenographic study of a series of 101 unselected cases of paralyzed



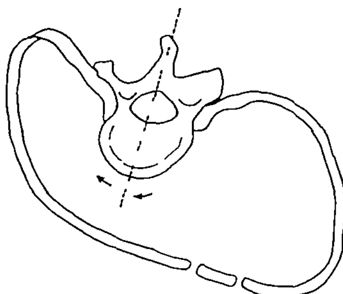


FIG 45 Cross section of thoracic deformity in dorsal scoliosis (67) Inset Cross section of normal chest

women showed that 79.2 per cent had an asymmetry of the pelvis, varying in degree and affecting the measurement of the pelvic inlet This asymmetry was not severe it probably accounts at least in part, for the lower incidence of dystocia due to bony abnormality in paralytic females. Chief among the factors responsible for the asymmetry was the distortion of the pelvic ring as a result of a primary or secondary lumbosacral rotary lateral scoliosis (Fig 44) which resembles the costal deformation (Fig 45) accompanying a dorsal rotary lateral scoliosis. The same type of pelvic deformity was also found in 4 cases of idiopathic lumbosacral scoliosis in which there was no evidence of paralysis Weight bearing obviously plays a role in this deformity of the pelvic ring and particularly so when the

weight is borne on a severely paralyzed limb and there is an associated atrophy of the pelvic bones. The authors of the study state

> The influence of shortening of a limb and of muscle imbalance, especially that involving the pelvic musculature, is difficult to evaluate, but we are impressed that these factors are more commonly effective indirectly when they initiate or exaggerate a lumbo-sacral scoliosis.
>
> The distortion of the pelvic ring arises from a deviation of its antero-posterior axis about a vertical axis. This axis deviation takes place almost frequently enough



Fig. 40. Left lumbosacral scoliosis with marked flattening of left side of pelvis (62)

> to be a constant accompaniment of lumbo sacral scoliosis [Fig. 46] in the direction of its convexity. It is secondary to the rotation of the lumbo-sacral spine as part of a rotary lateral scoliosis, the sacrum deviating in the direction of the convexity of the scoliosis and the symphysis pubis moving contralaterally. Other factors, such as shortening and muscle imbalance, are instrumental only where they initiate or exaggerate a lumbo-sacral scoliosis.

Special Types of Scoliosis

Rachitic Scoliosis

The essential pathology in rickets as it affects the spine is a softening and rarefaction of bone due to demineralization and inadequate calcifica-

tion and ossification of the vertebrae (Fig 47A–C) The weakened vertebrae give way to the body weight so that in some cases an anteroposterior deformity (kyphosis and lordosis) develops and in others a rotary lateral curvature Oppenheimer (73) thus describes the roentgenographic features

The roentgenologic appearances of vertebral rickets vary with the phases of the disorder General rarefaction prevails at early stages and when the disease progresses rapidly In less acute phases defined globular areas of rarefaction arranged like

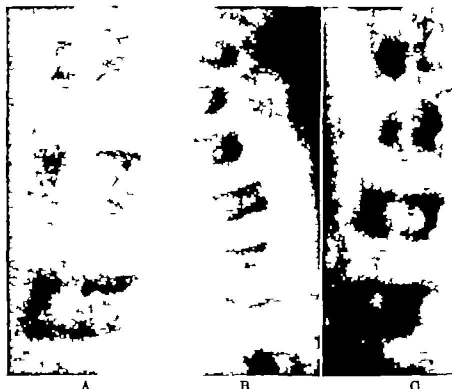


Fig 47 Rickets (73) A Active rickets the intravertebral defects correspond to enlarged medullary spaces B Advanced rickets note widening of disk spaces, flattening of vertebral surfaces and intravertebral areas of rarefaction C Severe rickets note intravertebral defects and wedging

clover leaves occupy the vertebral body they are surrounded by a layer of lime when the disease becomes arrested These areas correspond to the physiological vessel spaces in the vertebral body which are enlarged in rickets Broadening of the epiphyseal cartilages of the vertebrae was not observed Compression of vertebrae and expansion of intervertebral discs occurs as soon as rarefaction is sufficiently marked

The scoliosis remains after the early bone softening heals, and the vertebrae become thickened and sclerotic and little amenable to therapy

Congenital Scoliosis

Vertebrae and ribs may show a congenital variation in number in morphology or in both Purely numeric variations e.g eleven ribs or six

lumbar vertebrae do not cause scoliosis but morphologic variation with or without a numeric one is apt to lead to an asymmetric development



Fig 48 Congenital scoliosis due to hemivertebra

and scoliosis This type of scoliosis is termed "congenital scoliosis with manifest bony involvement The commonest morphologic changes which cause congenital scoliosis are

(1) *Hemivertebra* In this condition a part of a vertebral body, about

one half and usually wedge-shaped, is interposed between two apparently normal vertebrae (Fig 48) Its roentgenographic appearance is that of a triangle with the base on the side of the convexity

(2) *Maldeveloped vertebra* One-half of a vertebral body may be less developed than the other, resulting in a wedge vertebra or one-half of the body may be split off and be united with the vertebra above forming a wedge-shaped mass (Fig 49)

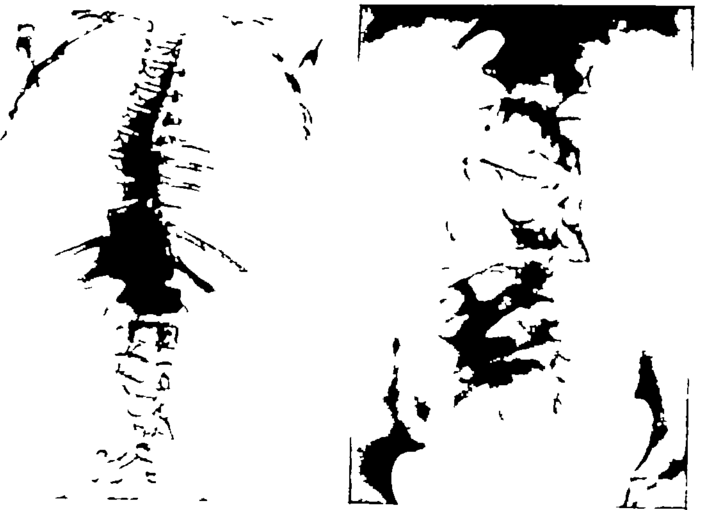
(3) *Fusion and maldevelopment of vertebrae* Several vertebrae may be extremely irregular and fused, forming one conglomerate wedge-shaped mass (Figs 50 and 51)

(4) *Spina bifida* Incomplete fusion of the posterior arch of one or more vertebrae occurs most commonly in the first sacral segment While in itself it is not a cause of scoliosis multiple such lesions associated with asymmetric development of the vertebrae do produce a scoliosis (Fig 52) In my experience this type of scoliosis occurs especially in the lower cervical and in the dorsal areas, in fact severe congenital curvatures are usually seen only in the dorsal or cervicodorsal areas (Fig 53)

Since congenital lesions tend to be multiple a wide variety of lesions, occurring anywhere in the body may be associated with the vertebral anomalies just described. Common deformities seen in association with congenital scoliosis are webbed fingers Sprengel s deformity cervical ribs, fused ribs and spina bifida occulta. The most common lesion other than that in the spine is a numeric and morphologic variation in the ribs in various combinations, such as absence of several ribs on one side fusion of several ribs or absence of several ribs and fusion of the others on the same or the opposite side (Fig 54) But whatever the change only when it is asymmetric does it produce a scoliosis Kuhns (58) in a study of 77 cases of congenital scoliosis found the spinal and costal malformations listed in Table II

Like other scolioses congenital scoliosis varies from a mild hardly noticeable asymmetry of the back to a severe deformity All types of curves have been found as may be seen from Kuhns' statistics (Table III)

Sacralization of Lumbar Vertebrae Occasionally the fifth lumbar vertebra is fused on one side to the sacrum (Figs 55 and 56) with or without scoliosis Dwight says it is difficult to describe a normal last lumbar vertebra because of its many variations. In some patients with scoliosis there is considerable asymmetry of the lumbosacral region so that sacralization added to asymmetric development of the fifth lumbar vertebra must be considered the cause of the scoliosis A variety of lumbosacral malformations have been encountered (Fig 57) A case of congenital scoliosis recently seen presented in addition to several other malformations a union



A B

Fig 49 Congenital scoliosis due to maldevelopment of third fourth and fifth lumbar vertebrae A Roentgenogram of spine B Congenital lesion initiating the scoliosis

one-half and usually wedge-shaped, is interposed between two apparently normal vertebrae (Fig 48) Its roentgenographic appearance is that of a triangle with the base on the side of the convexity

(2) *Maldeveloped vertebra* One half of a vertebral body may be less developed than the other resulting in a wedge vertebra or one-half of the body may be split off and be united with the vertebra above forming a wedge shaped mass (Fig 49)

(3) *Fusion and maldevelopment of vertebrae* Several vertebrae may be extremely irregular and fused forming one conglomerate wedge-shaped mass (Figs 50 and 51)

(4) *Spina bifida* Incomplete fusion of the posterior arch of one or more vertebrae occurs most commonly in the first sacral segment While in itself it is not a cause of scoliosis multiple such lesions associated with asymmetric development of the vertebrae do produce a scoliosis (Fig 52) In my experience, this type of scoliosis occurs especially in the lower cervical and in the dorsal areas in fact severe congenital curvatures are usually seen only in the dorsal or cervicodorsal areas (Fig 53)

Since congenital lesions tend to be multiple, a wide variety of lesions, occurring anywhere in the body may be associated with the vertebral anomalies just described Common deformities seen in association with congenital scoliosis are webbed fingers Sprengel s deformity cervical ribs, fused ribs and spina bifida occulta. The most common lesion other than that in the spine is a numeric and morphologic variation in the ribs, in various combinations such as absence of several ribs on one side fusion of several ribs or absence of several ribs and fusion of the others on the same or the opposite side (Fig 54) But whatever the change only when it is asymmetric does it produce a scoliosis Kuhns (58) in a study of 77 cases of congenital scoliosis found the spinal and costal malformations listed in Table II

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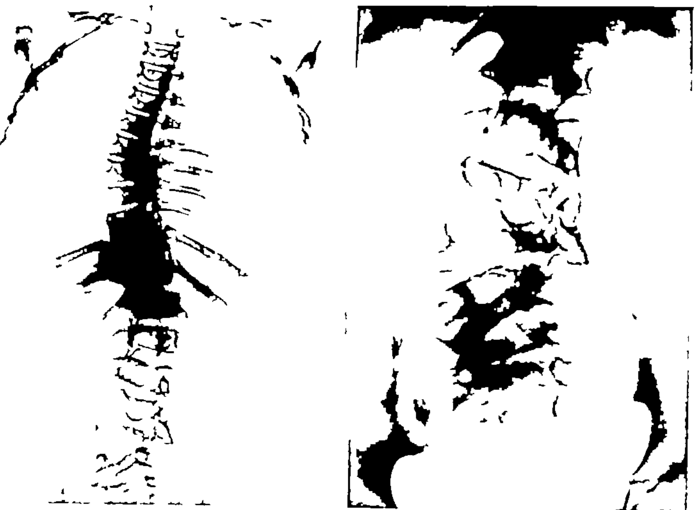


Fig 49 Congenital scoliosis due to maldevelopment of third fourth and fifth lumbar vertebrae A Roentgenogram of spine B Congenital lesion initiating the scoliosis



Fig 50 Congenital scoliosis due to wedged fusion of several vertebrae



FIG 51 Congenital scoliosis compensated as a result of multiple lesions on opposite sides of spine



Fig 50 Congenital scoliosis due to wedged fusion of several vertebrae



FIG 53 Severe congenital right dorsal scoliosis originally there were no manifest bone changes

of the fourth lumbar vertebra with the sacrum on one side through an osseous bar



Fig 52 Congenital scoliosis due to multiple vertebral anomalies

In a sizable proportion of patients with congenital spinal malformations there are lesions in more than one area of the spine Several types of mal formation may occur in one part of the spine or different types of lesions in different parts of the spine In one case for instance congenital lesions were present in four different sections of the spine

TABLE II

Spinal Deformities Found in Seventy-seven Cases of Congenital Scoliosis (68)

Type of deformity	Number of cases
Ribs	
Absence	
Unilateral	7
Bilateral	3
Supernumerary	
Unilateral	1
Bilateral	2
Fusion	
Unilateral	6
Bilateral	3
Vertebrae (suprasacral)	
Change in total number	
Less than 24	3
More than 24	1
Change in distribution	
6 lumbar 11 dorsal	2
4 lumbar 13 dorsal	1
Fusion	
Cervical region	1
Dorsal region	2
Lumbar region	2
Bifid	
Cervical	1
Dorsal	7
Lumbar	1
Hemivertebrae	
Cervical	3
Dorsal	5
Lumbar	3
Wedge shape	
Cervical	1
Dorsal	1
Lumbar	1
Spina bifida occulta	24
Platyspondylosis	4

Paralytic Scoliosis

Both the pathology and the classification of scoliosis resulting from poliomyelitis are the same as that due to any other cause. Nevertheless, there are some special characteristics that are worth discussion.

Mechanism. The basic cause of a postpoliomyelitic scoliosis is the muscle imbalance due to the asymmetric paresis or paralysis of the muscles of the



Fig 54 Congenital scoliosis associated with malformation of ribs

Carey (18), who adhered to the myogenic theory of scoliosis, designed an ingenious though complicated apparatus to show how muscle imbalance can produce scoliosis. Although he was well aware of the lack of accurate anatomic and physiologic knowledge of the mechanism which produces

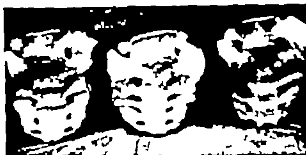


Fig 55 Sacralization of fifth lumbar vertebra more marked on left side (90)

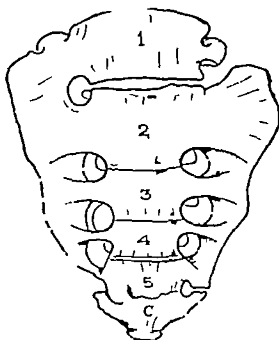


Fig 56 Transitional lumbosacral vertebra (82)

structural scoliosis he was of the opinion that normal balance of the back s motor system was maintained by the functional integrity of the blood nerves muscles tendons bones and joints. Scoliosis he believed is a spinal sign of the muscle tone imbalance of the back and is not a specific disease entity Focal muscular weakness and undernourishment, he believed often cause the imbalance that is a competent factor in scoliosis. Whether this theory is applicable in whole or in part to idiopathic

trunk and extremities Continuous automatic coordinated muscular function is essential for the symmetry of the trunk and for maintenance of the spine in the midline As soon as one or more trunk muscles cease to function or begin to function weakly the corresponding muscle or muscle group on the opposite side being unopposed begins to function relatively too strongly, and a muscle imbalance is established This imbalance operates continuously as witness the scoliosis which develops in continuously recumbent patients. The overaction of one or a group of muscles pulls a segment of the spine out of line, and initiates a scoliosis. However the deformity is more serious in patients who can maintain the upright position for the force of gravity is an important factor in aggravating the

TABLE III

Types of Curves Found in Seventy-seven Cases of Congenital Scoliosis (48)

Type of curve	Number of cases
Left cervical right dorsal	2
Left cervicodorsal right dorsolumbar	13
Left dorsal right lumbar	8
Left cervical right dorsal left lumbar	1
Left dorsal	5
Left lumbar	5
Right cervical left dorsal	2
Right cervicodorsal left dorsolumbar	3
Right dorsal left lumbar	18
Right dorsal	16
Right lumbar	4

curvature in all scolioses, and particularly in paralytic scoliosis There may be such extensive muscle weakness in patients with paralysis that unsupported sitting or standing markedly increases the scoliosis and the trunk grows shorter by two to eight inches Almost literally the trunk collapses like an accordion (Fig 58A, B)

It is true that scoliosis does not invariably develop in all patients with paralyzed trunk muscles It may be that in those patients in whom the paralysis attacked the muscles symmetrically the factor of asymmetric and unequal muscular activity is absent and there is no muscle imbalance. Colonna and vom Saal (21) found 21 cases of trunk paralysis without scoliosis in a series of 500 cases of poliomyelitis To quote these authors 'Without exception the trunk paralysis in each of these cases was almost completely symmetrical Conversely in over 500 unselected cases of poliomyelitis there was not a single case with marked asymmetrical trunk paralysis in which a scoliosis did not develop

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Fig 55 Sacralization of fifth lumbar vertebra more marked on left side (90)

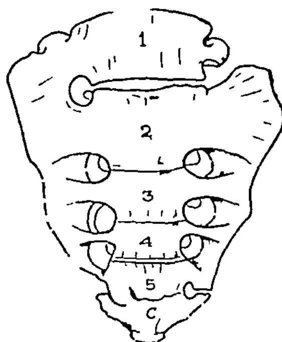


Fig 56 Transitional lumbosacral vertebra (32)

structural scoliosis he was of the opinion that normal balance of the back's motor system was maintained by the functional integrity of the blood nerves, muscles tendons bones and joints Scoliosis he believed is a spinal sign of the muscle tone imbalance of the back and is not a specific disease entity Focal muscular weakness and undernourishment he believed often cause the imbalance that is a competent factor in scoliosis. Whether this theory is applicable in whole or in part to idiopathic

scoliosis is open to question But it seems a reasonable assumption that in poliomyelitis and spastic paralysis disturbed muscle function can initiate a scoliosis.



FIG 57 Congenital scoliosis due to maldeveloped lumbar vertebrae and sacrum

It is extremely difficult to diagnose the exact degree of muscle paralysis in poliomyelitis, especially in paralysis of the trunk muscles. It is even at times impossible to identify unequivocally every muscle involved and to decide the degree of weakness or paralysis which affects the muscle in

question Clinical examination and the available electric and function tests do not invariably reveal the true state of muscle function

Colonna and vom Saal (21), who made an exhaustive study of 150 cases of paralytic scoliosis concluded that there is a definite relationship between paralysis of specific muscles and types of scoliosis They divided their cases into those with the convexity of the curve toward the stronger muscle groups (Group A) and those with the concavity of the curve toward the stronger muscle groups (Group B)

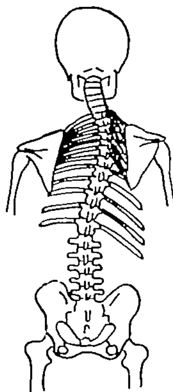


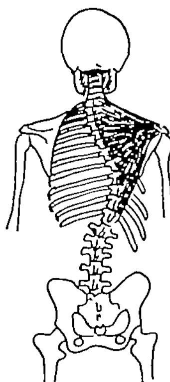
Fig 58 Paralytic scoliosis (21) A Collapse of trunk B Potential lengthening of trunk

Group A Unequal pull of the iliopsoas muscle was present in 29 of 103 cases and was apparently the principal factor in producing the curve the same type of curve was found in 14 of 120 patients with paralysis of the gluteus medius muscle Of 85 patients with paralysis of the gluteus maximus muscle 11 had a curvature with the convexity toward the stronger side of 63 patients with paralysis of the latissimus dorsi muscle 34 had such a curve and in 6 of them the paralysis of this muscle seemed to be the sole cause of the curvature A similar curve was found in patients with paralysis of the rhomboid muscle (Fig 59) and of the trapezius muscle (Fig 60) in 30 out of 42 patients with rhomboid paralysis and in 28 with trapezius paralysis there was a pull toward the sound side Deltoid paralysis produced such a curve in 23 of 45 patients (Fig 61)

Group B The importance of asymmetric paralysis of the abdominal muscles has been recognized (64) In the series reported by Colonna and vom Saal 31 cases presented the concavity of the curve toward the side of the unaffected abdominal muscles. There were a total of 200 paralyzed muscles in this group of cases, 126 involving the obliquus abdominis muscles and 74 the rectus abdominis muscles

In patients with paralysis of the sacrospinalis muscles, an important





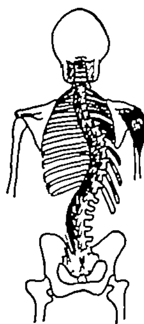


Fig 59 Fig 60 Fig 61

Fig 59 Paralytic scoliosis secondary to involvement of the rhomboid muscles (21)
Fig 60 Paralytic scoliosis secondary to involvement of the trapezius muscle (21)
Fig 61 Paralytic scoliosis secondary to involvement of the sacrospinalis and deltoid muscles (21)

factor in the development of many of the dorsal curves, the muscle pull was asymmetric in 19 of 46 patients in whom these muscles were involved (Fig 62) The same obtained for 28 out of 40 patients with paralyzed quadratus lumborum muscles In both groups the concavity was toward the sound side In the 12 patients with symmetric paralysis of the quadratus lumborum there was no scoliosis.

The subject of paralytic scoliosis, however is not really as simple as would appear from the above outline. In my experience there is often such a combination of muscle paralyses that it is impossible to pick out the muscles specifically responsible for the curvature. To complicate mat

ters, paralyses and contractures of the pelvitrochanteric muscles with a resultant fixed pelvic obliquity as pointed out by Mayer (65, 66), are important factors in lumbar and lumbosacral scolioses

The neurogenic element is undoubtedly another important factor in paralytic scoliosis, although its rôle cannot be evaluated accurately Like the long bones, which suffer trophic or nutritional changes in poliomyelitis and become atrophied and shortened, the vertebrae may suffer neuro

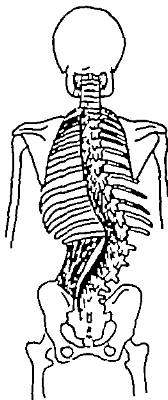


Fig 62 Paralytic scoliosis secondary to involvement of the sacrospinalis and quadratus lumborum muscles (21)

vascular changes resulting in morphologic alterations and ultimately in scoliosis

Incidence In my experience scoliosis occurs in about 5 per cent of patients with poliomyelitis and about 5 per cent of all scolioses are paralytic Cobb (20) agrees with me and other workers who have found an incidence of about 5 per cent Colonna and vom Saal, on the other hand, found an incidence of 30 per cent of scoliosis among 500 unselected cases of poliomyelitis. A further surprising fact is that in their scoliosis clinic 62 per cent of all scolioses were paralytic in origin I believe such a large proportion of paralytic scoliosis to be unusual and that it is not generally the experience of orthopaedic clinics In my nearly forty years of work in scoliosis, I have found 70 to 80 per cent of the scolioses (including the hereditary) to be idiopathic without any history of poliomyelitis and

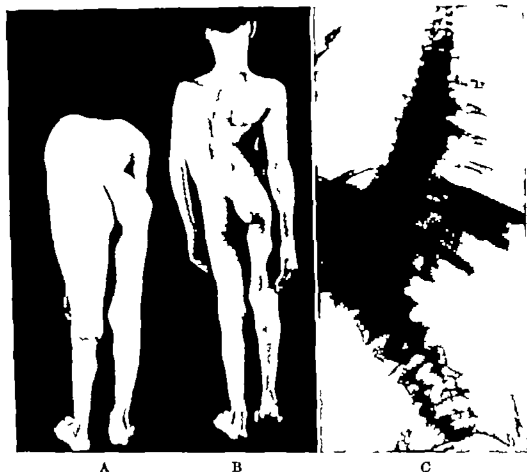
without the slightest sign of muscle paralysis. This is of importance in connection with the therapy of scoliosis, and will be considered at greater length in the chapter on treatment



FIG 63 Paralytic cervicodorsal scoliosis

Paralytic scoliosis makes its appearance any time between 1 and 10 years after the acute phase of poliomyelitis has subsided. In contrast to the idiopathic type, which is most unlikely to become more severe, once

growth is completed, i e, after about the age of 16, paralytic scoliosis not only may appear after this age, but can also grow worse In fact, a sad characteristic of this type of scoliosis is that it tends to increase at almost any age until it attains a severe degree Colonna and vom Saal found 4 cases in which the curvature developed after the age of 16 though repeated measurements showed no further growth, and in 1 case a severe



A B C

Fig 64 Paralytic dorsolumbar scoliosis A Patient in forward bent position B Patient in upright position C Roentgenogram of spine

scoliosis appeared at about the age of 20 The reason for this difference is not hard to see in the idiopathic group there are a number of causes responsible for the scoliosis all apparently operating only or mainly during the growing period in paralytic scoliosis on the other hand the chief agent is the unequal muscle paralysis which can produce asymmetry in position and resultant deformity at any age

Types Like any other curvature paralytic scoliosis varies in type and degree The three major forms are a high cervicodorsal kyphoscoliosis (Fig 63) a long dorsolumbar scoliosis (Fig 64), and a lumbar or lumbosacral scoliosis (Fig 65), with numerous gradations between the three

Irwin (48) divides paralytic scoliosis into six separate groups, namely, (*1*) lumbosacral scoliosis with a fixed pelvic obliquity (*2*) lumbosacral scoliosis with the pelvis a part of the curve as a scoliotic pelvis, (*3*) a long C curve involving the dorsolumbar region, (*4*) a dorsolumbar curve with the dorsal segment as the primary or fixed curve, (*5*) a dorsolumbar curve, with fixation in both dorsal and lumbar segments (*6*) cervicodorsal scoliosis and kyphosis Actually this classification differs little from the one



Fig 65 Paralytic lumbar scoliosis A Patient seated trunk markedly shortened B Roentgenogram of spine

proposed by me the first two are practically the same and the next three are merely variations of the same general type of scoliosis.

Since the gross external changes in the body and the conformation and internal structure of the vertebrae ribs, and all other structures of the trunk are the same in paralytic as in idiopathic scoliosis, the description will not be repeated.

Muscles

The muscles of the back and trunk are subject to primary and secondary changes. The primary changes follow such illnesses as poliomyelitis amyotrophic *lateral sclerosis or Erb's palsy and are direct or contributory* causes to the production of scoliosis. The secondary changes in the muscles are consequent to and a direct sequel of the scoliotic deformity Not only the muscles of the back and trunk but those of the neck and the shoulder

and pelvic girdles, are affected The primary changes were described under paralytic scoliosis The secondary changes occur because the muscles, like the other tissues, adapt themselves to the altered shape and posture of the spine, chest pelvis and neck Some muscles remain active and may even hypertrophy, but others atrophy through diminution or loss of function Fatty degeneration has been noted in the muscles of both sides of the back Over the convexity the muscles are often thinned out and in places they may even become fibrous In general, the muscles of the back are weakened

Skull

In my experience comprising hundreds of cases there is no asymmetry of the face or skull except in cases following or accompanied by torticollis In the latter cases there is an atrophy of one side of the face and skull

Internal Organs

In structural scoliosis all of the soft tissues and the internal organs are affected in direct proportion to the degree of the deformity (Fig 60) In mild cases the changes in the organs are negligible in the severe cases the structural alterations and functional disturbances are marked and between these two extremes are all gradations.

Lungs

On the side of the convexity the lung is compressed the extent of compression depending on the severity of the deformity In extreme cases the lung on the convex side may be atelectatic On the concave side the lung is not much disturbed, at times it is enlarged from hyperactivity However it has not been my experience that tuberculosis of the lungs presents a particular problem or hazard in scoliosis except when thoracoplasty becomes necessary Nor do patients with scoliosis seem to suffer to a greater extent than other people from the common respiratory infections patients with extreme chest deformities excepted The altered structure and function of the lungs do however, materially reduce the vital capacity

Heart

There is frequently a lateral and occasionally a downward displacement of the heart and I have observed a case in which the heart was not only displaced downward but was also considerably elongated Hypertrophy and dilatation especially of the right side of the heart are characteristic of severe scoliosis due to the increased tax on the heart as a result of the deformity and the obliteration of part of the lung tissue These structural and functional changes are secondary to the scoliosis In a report on 4 cases of severe scoliosis resulting in hypertrophy and dilatation of the

heart with cardiac insufficiency (28), kinking and narrowing of the aorta was found at autopsy in one case, and of the pulmonary artery in another

It has been my experience that patients with *marked* scoliosis and

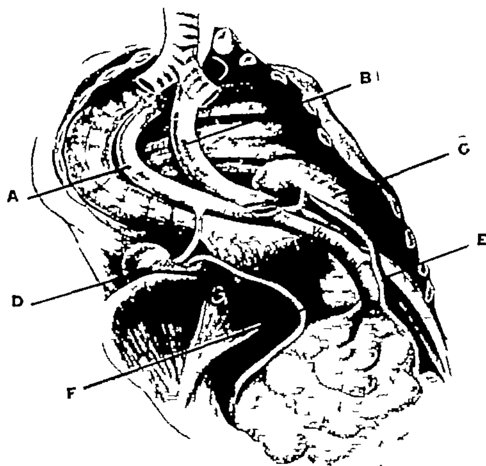


FIG 66 Right dorsal scoliosis (72) Note distortion of chest deviation of aorta and esophagus toward the convexity of the curve distorsion of inferior vena cava and right psoas muscle. *a*, Aorta *b* Esophagus *c*, Left kidney *d* Right kidney *e* Left ureter *f* Right ureter

thoracic deformity rarely live beyond the age of 45 which is to be expected in view of the intrathoracic and intra-abdominal pathology in such cases. On the other hand in mild scoliosis the life-span expectancy does not differ from that of other people

Scoliosis may occur as a result of marked cardiac enlargement due to endocarditis and myocardial dilatation and hypertrophy One such case

was reported by Lee (59) In the few cases of this type which I have seen the curvature was rather mild and the etiologic relationship was assumed on the basis of chronology, the heart lesion having been discovered and observed before the scoliosis was noticed

The deformity in Lee's case started at about the same time as do most idiopathic curves and it is possible that the association of heart disease and scoliosis in this case was purely coincidental Theoretically, although the exact mechanism of a scoliosis secondary to heart disease is obscure, a hypertrophied heart may initiate asymmetric posture and eventually lead to a structural scoliosis

Other Thoracic Organs

The aorta is deflected from its normal course generally following the direction and curve of the spine The esophagus is also disturbed though less than the aorta It is displaced from the midline but as a rule in a long curve it follows its ordinary course Other structures—the diaphragm, arteries veins, nerves—are, obviously, distorted in length and position in varying degrees

Abdominal Organs

The intestines are usually crowded into the lower part of the abdomen The stomach is often lowered and elongated so that it lies vertically with the pyloric end well below the umbilicus. The other organs are frequently disturbed and displaced from their normal positions. The liver and spleen may be misshapen from pressure of the neighboring deformed ribs. The function of the abdominal organs is less frequently disturbed than those of the thorax Gastrointestinal disturbances are encountered, but only in the severe cases in which there is marked shortening of the trunk and great crowding of the abdominal organs.

SPINAL CORD

Paralysis of the limbs as a result of structural scoliosis is exceedingly rare In an experience of over forty years and thousands of cases I have seen only 2 cases. McKenzie and Dewar (60) have recently published a most comprehensive study of this phase of scoliosis From the literature they collected and analyzed reports of 41 cases of paraplegia complicating scoliosis including 5 cases of their own The majority of the patients were male The scoliosis was severe characterized by marked kyphosis and in every case was in the dorsal segment of the spine, the level of cord damage nearly always corresponded to the apex of the deformity The age distribution was 33 patients between the ages of 12 and 19 years at the onset of cord compression signs 2 patients, 6 years old and 6 patients between 20 and 23 years of age

The essential pathology is a compression of the spinal cord by the dura. In one case a tight extradural band was found, in another a bony over growth which manifestly caused the cord compression, in a third, syringomyelia

'Study of twenty four cases treated by operation shows that the cause of paraplegia was the combination of a tightly stretched dura and a sharply angulated spinal canal the point of maximal pressure by the dura being localised at the angle of the spinal canal If then the cord is in fact compressed the compression must be from the tightness of the dural sac The sac is attached more firmly to the foramen magnum above and the sacrum below than it is to the sides of the spinal canal by its prolongations on the nerve roots If it is taut it will resist the tendency of the spinal cord to be displaced from a straight line by deformity thus explaining localisation of the lesion to the apex of the curve The lumen of the dural sac must be narrowed still further by rotational displacement

It seems probable that the exciting cause which precipitates paralysis is the rapid growth of the spinal column together with the inability of a tight dura to accommodate itself to such growth

In the last three years 3 additional cases have been reported (47 61) and a report of my second case is about to appear bringing the total number of cases of paraplegia complicating structural scoliosis to 45

Hyndman s (47) patient was a 10-year-old boy in whom paralysis developed in a few months until there was almost total motor paralysis. A roentgenogram showed a marked right dorsal scoliosis, with the apex of the curve at the level of the sixth dorsal vertebra On operation the cord except for a marked rotation and angulation appeared normal Hyndman concluded that the acute angulation of the cord was responsible for loss of function

Love and Erb s (61) 2 patients were a boy of 11 and a boy of 17 the former had a paralytic kyphoscoliosis, the latter a congenital scoliosis due to a right fifth dorsal hemivertebra In both there was a bony ridge in front of the cord Upon removal of this ridge the cord fell forward into an anterior position In the first patient the cord was compressed at the apex of the deformity in the second definite kinking of the cord was found on operation.

My own recent case is that of a 12-year-old girl who was admitted to the hospital for paralysis of the lower limbs and increasing deformity of the back She had a marked kyphosis at the dorsolumbar junction and the roentgenogram revealed a dorsolumbar angular kyphoscoliosis due to a congenital hemivertebra between the tenth and eleventh dorsal vertebrae (Fig 67)

The pathologic conditions in scoliosis which may lead to paraplegia can be summarized as (*1*) marked kyphosis (*2*) tightness of the dura



FIG 67 Anteroposterior roentgenogram showing dorsolumbar angular kyphoscoliosis due to a hemivertebra on the right side between the tenth and eleventh dorsal vertebrae with paraplegia as a complicating result

(3) bony spurring of the neural canal (4) extradural anomalous pressure band (5) osseous ridge at the apex of the curve in front of the spinal cord, (6) acute angulation of the cord

Mobility of Spine

As the spinal deformity develops, the motion of the spine becomes limited the extent of limitation depending on the severity of the deformity Motion grows more and more restricted as the curvature increases In mild cases spinal motion is not perceptibly limited, and with curvatures that are mainly in the thoracic area there may be little restriction even in moderate scoliosis, since the lumbar region is the section of the spine with freest motion

Of vital importance is the degree of vertebral rotation, for the greater the rotation the more restricted the motion In scolioses with marked lateral displacement but little vertebral rotation, as in some cases of paralytic scoliosis motion is only slightly limited and the deformity can be greatly improved. Conversely the more restricted the spinal motion the greater is the severity of the deformity and the less hopeful is the prognosis. The main causes of restricted spinal mobility in scoliosis are (1) vertebral deformity (2) rib deformity (3) intervertebral disk deformity (4) adaptive shortening of ligaments and muscles on the concave side of the curve (5) vertebral fusion (6) ossification of ligaments.

Rotation and Deviation

The two chief elements in every scoliotic deformity are vertebral deviation and rotation Deviation is indicated by lateral displacement of the vertebral spinous processes rotation, by the backward projection of the ribs in the thoracic region, and by the prominence of the transverse processes in the lumbar and cervical regions. The rotation is always toward the convex side of the curve. The two conditions rarely correspond in degree, although they always coexist Marked deviation is frequently found together with moderate rotation or vice versa. Vertebral rotation is of greater import than deviation in the prognosis and therapy of scoliosis.

Because of the intimate connection between ribs and vertebrae, rotation is more evident in the thoracic than in the lumbar and cervical regions. The greater the rotation of the dorsal vertebrae the more marked the distortion of the ribs and chest. Extreme spinal deviation accompanied by only moderate vertebral rotation on the other hand, often yields to treatment and the appearance of the back can be considerably improved. Fixed rotation of the vertebrae implies structural changes in the vertebrae, ribs, and soft tissues and the more marked the rotational deformity the



Fig 68 Lordosis

more advanced the structural changes. The degree of vertebral rotation is a measure of the severity of the deformity

Round and Flat Back

Normally the spine has a physiologic anteroposterior curve In scoliosis, this curve is often increased or decreased. When the dorsal curve is in-

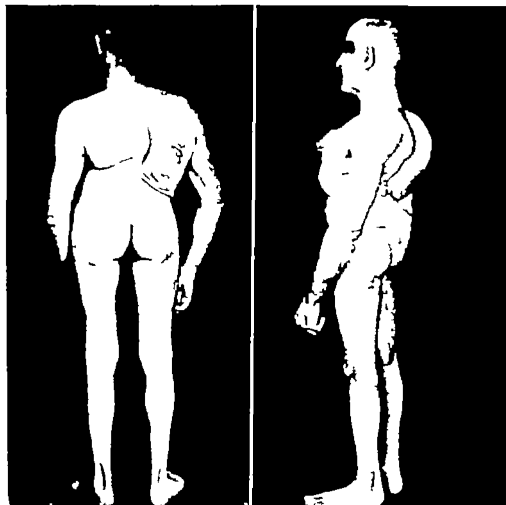


Fig 69 Severe scoliosis and pigeon chest

creased as sometimes happens in stocky children with long dorsal and short lumbar curves or in paralytic cervicodorsal curves, a kyphoscoliosis results and there is usually severe rotation deformity When the dorsal curve is diminished, the back appears flattened, and is spoken of as flat back there is only a slight rotation in these cases

Lordosis

In lordosis there is an increase of the normal anterior curvature of the lumbar spine an exaggeration of the hollow in the small of the back (Fig

68) In scoliosis it occurs as a compensatory curve to a dorsal kyphoscoliosis. It is often concomitant with round shoulders or dorsal Pott's disease. It may be secondary to contraction of the hips as a result of bone disease or paralysis. In older children it has been observed with, and by some has been considered the cause of, orthostatic albuminuria. Rarely, it is congenital, due to malformation of the lumbar vertebrae.

Pigeon Chest

A complication occasionally occurring with the severest grades of scoliosis is the so-called pigeon-chest deformity, in which the anteroposterior diameter of the chest is increased, with unusual prominence and forward projection of the sternum (Fig. 69).

more advanced the structural changes. The degree of vertebral rotation is a measure of the severity of the deformity

Round and Flat Back

Normally the spine has a physiologic anteroposterior curve. In scoliosis, this curve is often increased or decreased. When the dorsal curve is in

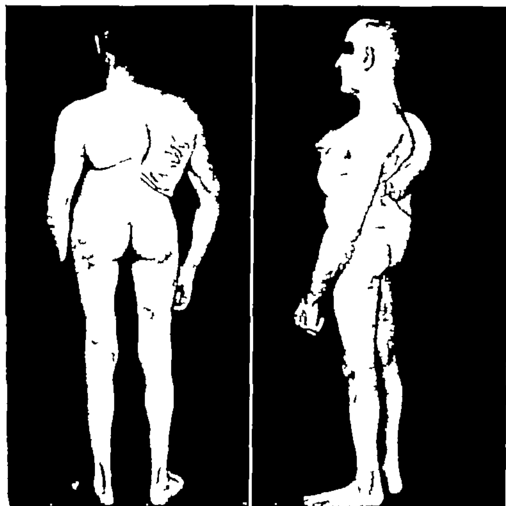


Fig 69 Severe scoliosis and pigeon chest

creased as sometimes happens in stocky children with long dorsal and short lumbar curves or in paralytic cervicodorsal curves a kyphoscoliosis results and there is usually severe rotation deformity When the dorsal curve is diminished the back appears flattened and is spoken of as flat back there *is only a slight rotation in these cases*

Lordosis

In lordosis there is an increase of the normal anterior curvature of the lumbar spine an exaggeration of the hollow in the small of the back (Fig

d Neurofibromatosis (36, 37)
e Hysteria
3 Rickets
4 Faulty posture
5 Unequal length of lower limbs
6 Visual or auditory disturbances
7 Torticollis organic or functional
8 Thoracic disease or surgery
a Empyema
b Pulmonary tuberculosis
c Bronchiectasis
d Pneumothorax
e Pyopneumothorax
f Pulmonary tumor
g Thoracoplasty
9 Spinal disease
a Spondylitis deformans
b Fracture or dislocation
c Osteomalacia
d Dyschondroplasia
e Vertebral epiphysitis
f Syphilis
g Tuberculosis
10 Organic heart disease
11 Heredity
12 Miscellaneous (fragilitas ossium etc)

Congenital Scoliosis

Without Manifest Bone Changes There are occasional reports of scoliosis in early infancy which has been present from birth Possibly this apparently congenital curvature is based on some asymmetric development of the skeletal muscles or diaphragm According to Kuhns (58), this type of scoliosis is not common usually corrects readily under treatment and remains normal ' I myself have seen only four such cases, in three of which there was considerable lateral deviation of the spine but only slight vertebral rotation. One of these three patients had a moderate right dorsolumbar scoliosis (Fig 71) and an apparent imbalance of the abdominal muscles which were spastic on the left side and flaccid on the right A plaster of Paris jacket readily corrected the scoliosis but as soon as the jacket was removed the curvature recurred The fourth patient came under my observation at the age of 2 months and has remained with me since then He is now 10 years old He had a mild seemingly triple suprasacral curve with a bulging of the left side of the abdomen. No specific etiology could be established Despite continuous vigorous treatment the deformity has progressed to a severe degree like others of the idiopathic variety

The pathogenesis of this type of scoliosis is obscure and its elucidation

CHAPTER IV

ETIOLOGY

FUNCTIONAL SCOLIOSIS

So far as a functional curvature of the spine is concerned it is generally agreed that any condition which favors or induces habitual faulty posture can initiate a functional scoliosis particularly in children with a constitutional predisposition for curvature The various causes are listed in the outline below

I Improperly adjusted clothing giving rise to unequal pressure or traction on the shoulders
II Maladjusted desks and seats, inducing prolonged abnormal positions of the body while sitting
III Defective hearing or vision
IV Malnutrition weakening the musculature and subjecting it to undue strain
V Asthenia
VI Shortening of a lower limb from whatever cause (Fig 70)
VII Faulty postural habits in childhood occupations e g in drawing writing reading playing the piano or violin

STRUCTURAL SCOLIOSIS

The problem of determining the etiology of structural scoliosis is much more difficult Much thought and work has been devoted to this question experiment has been utilized, and theory called upon to arrive at a likely or at least a probable explanation of its pathogenesis. As yet no common factor has been discovered which serves for all types of structural scoliosis A variety of factors, therefore, each of which may be a potential and plausible cause in some cases must be accepted The following is a practical summary of the causes of scoliosis.

I Congenital Scoliosis
 A Without manifest bone changes
 B With manifest bone changes
II Acquired Scoliosis
 A Origin unknown or idiopathic
 B Origin known
  1 Paralysis due to poliomyelitis
  2 Nervous system diseases (other than poliomyelitis
   a. Friedreich s ataxia
   b Syringomyelia (55)
   c Spastic paralysis

side of the wedge, but if a similar wedge mass be present a little above or below it, clinically the spine as a whole remains in the midline of the body



FIG 71 Congenital right dorsolumbar scoliosis without manifest bone involvement

Or many most or all of the vertebrae may be maldeveloped wedging is absent however and the scoliosis may be very mild The scoliosis which results from congenital osseous malformation may remain mild or progress

must be left to such time as more cases have been analyzed with respect to embryology and prenatal conditions of mother and fetus

With Manifest Bone Changes Congenital malformations of the vertebrae and ribs are relatively common but a scoliosis is produced only in the



A B

Fig 70 Functional left lumbar scoliosis secondary to shortened left leg due to septic arthritis in infancy and subsequent dysplasia of bones A Patient standing B Patient sitting scoliosis has disappeared

presence of a developmental asymmetry (Fig 72) The various congenital lesions of the spine have been described in Chapter III So long as the general balance of the spine is not disturbed there may be little clinical evidence of the scoliosis and it is discovered accidentally When a single vertebra is involved there may be a short curve which is adequately compensated by a short curve above or below it Several maldeveloped vertebrae may form a wedge mass, with the spine deviating toward the convex

side of the wedge But if a similar wedge mass be present a little above or below it clinically the spine as a whole remains in the midline of the body



Fig 71 Congenital right dorsolumbar scoliosis without manifest bone involvement

Or many, most, or all of the vertebrae may be maldeveloped wedging is absent, however and the scoliosis may be very mild The scoliosis which results from congenital osseous malformation may remain mild or progress

until it becomes a moderate or severe deformity Why in some instances the scoliotic process is arrested and in others it is aggravated remains unexplained In some cases, treatment will limit development of the scolio-

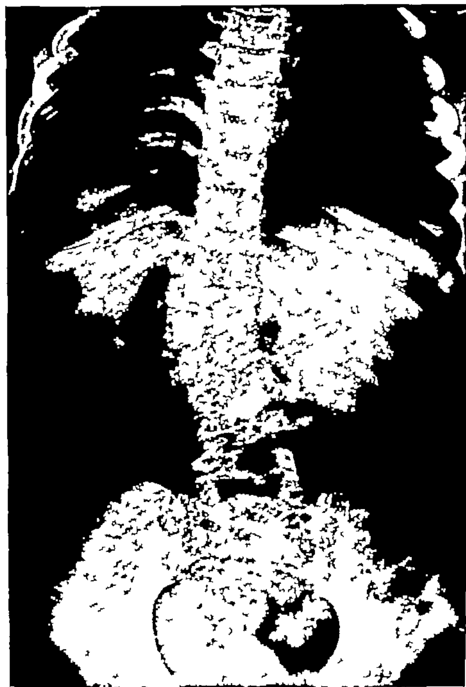


Fig 72 Congenital scoliosis in infant with manifest bone involvement at dorsolumbar junction

as, in others vigorous, continuous seemingly adequate treatment does not halt the progress of the deformity As in idiopathic scoliosis there is some as yet unknown factor at work—perhaps a purely mechanical one but more probably a developmental quirk

A congenital scoliosis is not usually discovered at birth, since in few cases is there any gross external evidence of the deformity at this time

TABLE IV

Data on Congenital Scoliosis Among 330 Cases of Structural Scoliosis

Total number of cases	330
Total number of congenital scolioses	17
Number of females	9
Number of males	8
Number without manifest bone changes	3
Number with manifest bone changes	14
Manifest bone changes found	
Hemivertebra	
Wedge formation of several vertebrae	
Fused vertebrae	
Dysplasia of sacrum	
Maldevelopment of vertebrae	
Fused ribs	
Supernumerary ribs	
Age when first discovered and number of cases	
At birth	5
3 months	1
4 years	1
5 years	1
8 years	1
13 years	2
14 years	1
15 years	1
21 years	2
27 years	1
34 years	1

Kuhns (58) statistics on this point are interesting In his series of 77 cases of congenital scoliosis 18 curvatures were noticed at birth 11 during the first 6 months 19 before the age of 2 years and 14 after the age of 6 years nearly 25 per cent therefore, were not discovered until after the age of 6 years In one of my series only 8 of 17 cases or less than 50 per cent were discovered before the age of 6 years and 4 patients were over 20 years old (Table IV)

The incidence of congenital scoliosis among Kuhns cases was 11 per cent (77 out of 681 cases of structural scoliosis) In general the incidence of this type of scoliosis is believed to be considerably lower In my own

experience it is between 4.5 per cent and 5 per cent 9 cases of congenital scoliosis in an earlier series of 198 cases of structural scoliosis (4.5 per cent), and more recently 17 among 330 cases, or 5 per cent (Table IV) Cobb (20) has found an incidence of 2 per cent among his cases

Idiopathic Scoliosis

In a large majority of scolioses the pathogenesis is not apparent and the deformity is termed "idiopathic Seemingly out of a clear sky, a curvature will start in a child and progress until it is recognized by the gross changes in the contour of the trunk The scoliosis may remain mild throughout life or it may grow moderately or severely worse In some cases it may be modified by treatment in others be utterly uninfluenced by therapy This large proportion of unexplained scolioses has shrunk somewhat in the past two decades as a result of intensive study and research but by and large the etiology and pathogenesis of idiopathic scoliosis remains an unilluminated page.

Scoliosis of Known Origin

Here are grouped a large number of causes, each of which seemingly predominates in the production of some scolioses A number of theories have been evolved to explain the *modus operandi* of the various causes in the production of rotary lateral curvature of the spine

Mechanical Theory The majority of scolioses begin between the ages of 6 and 10 years as a mild deformity How and why do they so often progress until the curvature has attained varying degrees of severity? Let us assume that an 8-year-old child is in the habit of standing and sitting with the right shoulder higher than the left and the trunk tilted toward the right The habit may have developed because of general malnutrition exhaustion after a prolonged or severe illness piano or violin playing in a faulty posture maladjusted clothing exerting unequal pull on the shoulders, poor seating arrangements in school or at home deficient hearing or vision or any one of many other causes. This habitual faulty posture leads to asymmetric pressure and traction on the vertebrae and adjacent tissues, with resultant increase of bone density on the concave side and diminished density on the convex side (Hueter Volkmann rule)

Concurrently the soft tissues on the concave side contract and those on the convex side stretch Furthermore as has been shown frequently the vertebrae segmental elements of a column which has several alternating anteroposterior curves, deviate to one side and also rotate toward that side. Thus we have the beginning of a rotary lateral curvature. The weight of the body tends to increase the curvature. Once established the rotary lateral curvature increases slowly but steadily

Structural changes take place in the vertebrae, ribs, ligaments muscles, and viscera, and if allowed to continue become fixed (Wolff's law) Compensatory curves develop as a result of the automatic efforts of the individual to maintain the upright position with the center of weight over the center of gravity

In this first stage of faulty posture the scoliosis is functional and can be corrected voluntarily and easily Many, perhaps most cases never go beyond this stage Why in others the bones and soft tissues undergo structural change has been the subject of many theories One theory postulates the existence of an inadequacy or insufficiency of the spine in resisting the functional stresses and assumes that the prescoliotic stage "signifies a clinical period of latency during which the underlying pathologic conditions are present but no unmistakable signs of scoliosis have appeared

The prescoliotic stage is characterized by anomalies in carriage and posture (87) According to another theory (70), any habitual faulty attitude assumed by a growing child distributes the weight of the body unequally and is the direct cause of the deformity This however, happens only in children with an inadequate or susceptible spine, some deficient metabolic factor an X factor

All organic or structural scolioses are mild at first, and many remain so Others especially in early adolescence when there is a sudden spurt in growth and weight increase to the moderate or severe stage Whether this increase is the result of a purely mechanical factor i e. increase in weight is not known Bisgard and Musselman (13) who studied the effect of partial interference with the physiologic development of the vertebral epiphyseal plates have suggested that as the scoliosis continues the unequal pressure on the plates on the concave side of the curve retards the normal growth of the vertebrae on this side while on the convex side the development is normal or even greater than normal This results in wedging of the vertebrae greatest at the apex of the curve and slighter at a distance from the apex

Fortunately judicious and persistent treatment can in many cases prevent the scoliosis from becoming severe though in some instances even vigorous and uninterrupted treatment will not arrest further development of the scoliotic deformity

Carey (18) believed that focal muscular weakness and undernourishment often cause imbalance in the tissues. While theoretically possible it is noteworthy that many of these patients appear physically sound and of good muscular development Certainly in my own experience I have not found any clinically recognizable evidence of muscle weakness or unequal muscle strength in the patients that have come to me whatever the degree of scoliosis except in postpoliomyelitic patients

Muscle Imbalance The mechanical theory assumes the existence of faulty posture as the initial stage However, there are circumstances, as in poliomyelitis, in which muscles become paretic or paralyzed and a manifest muscle imbalance is created In about 5 per cent of poliomyelitic patients with paralysis a scoliosis develops, even if the patient is kept in bed Since in these patients the two sides of the body are rarely affected symmetrically a state of muscle imbalance exists whatever the position of the patient, and obviously in such a state unequal pull on the spine might initiate a scoliosis

Colonna and vom Saal believe that there is a distinct pattern in the relationship between specific muscle paralysis and certain types of scoliosis. But my own observations lead me to doubt whether it is possible to evaluate accurately the exact nature and extent of the muscle imbalance in all or even in many cases of paralytic scoliosis In the first place a given pattern of muscle imbalance does not invariably lead to a specific type of scoliosis. Furthermore the muscles on the concave side of the curve are often seemingly weaker than those on the convex side when theoretically the opposite should be true I have also found that a scoliosis sometimes develops even in the absence of recognizable involvement of the skeletal muscles of the back, chest, abdomen, or diaphragm All too frequently the scoliosis becomes progressively severe out of all proportion to the apparent muscle involvement Last, but not least there is the likelihood of a neurogenous, trophic or nutritional disturbance in the vertebrae which is the direct result of the poliomyelitis This may account for the *asymmetry of some or many of the vertebrae and associated soft tissues,* very like the marked postpoliomyelitic shortening of the bones of a lower limb with comparatively slight muscle paralysis. All of the reasons given lead me to assume that as in the mechanical theory there is an unknown or X, factor at work.

Unequal involvement of muscles attached to the pelvis may cause a fixed pelvic obliquity In this connection Mayer (65 66) emphasized two varieties of muscle imbalance which may cause scoliosis One is that in which there is a muscle imbalance below the pelvis (Fig 73) It may be the result of adductor paralysis of the thigh only but is usually combined with an abduction contracture of the pelvifemoral muscles on the same side the result is an apparent lengthening of the limb a downward tilt of the pelvis on this side and a lumbar scoliosis with the convexity on the same side The other type is that in which there is a paralysis above the pelvis (Fig 74) i.e. in the trunk muscles most frequently the abdominal muscles the quadratus lumborum, and the erector spinae Any imbalance here can initiate a scoliosis. For instance if the abdominal muscles or the trunk muscles *on the right are paralyzed the unopposed muscles on the*

left will contract and cause a scoliosis with the convexity toward the paralyzed side The following is quoted from Mayer's paper

> Many cases of paralytic scoliosis are not complicated by obliquity of the pelvis Despite a marked curve or tilt of the body the pelvis remains horizontal and the length of the legs equal What causes the marked tilt in some cases is still a matter of conjecture I believe it is due to a paralysis of the spinal and abdominal muscles of



Fig 73 Paralytic right lumbar scoliosis secondary to contracture of right thigh abductors and left thigh adductors (67)

> one side with retention of power on the other side If in addition the quadratus lumborum is also paralyzed on the one side but active on the other a downward tilt of the paralyzed side would seem to be inevitable

It is generally accepted that muscle imbalance in the trunk, whatever the cause can initiate a scoliosis In poliomyelitis, irregular paralysis or paresis, is the rule rather than the exception Except possibly in complete paralysis of the abdominal wall the paralysis is almost never symmetric It follows that there must frequently be a muscle imbalance in poliomyelitis with a strong possibility of a resultant scoliosis

The theory of muscle imbalance after poliomyelitis seems so plausible that some workers see a paralytic origin in most cases of scoliosis. Hibbs and his co-workers (42) for example, reported that 44 per cent of 360 cases of scoliosis were secondary to poliomyelitis, while Colonna and vom Saal (21) believed that 62 per cent of the cases in their scoliosis clinic were of paralytic origin This is in sharp contrast to the experience of many workers in this field, including myself It is generally accepted that the incidence of paralytic scoliosis is between 5 and 10 per cent That scoliosis does complicate poliomyelitis is incontrovertible But other factors than muscle paralysis are manifestly dominant in many cases of structural

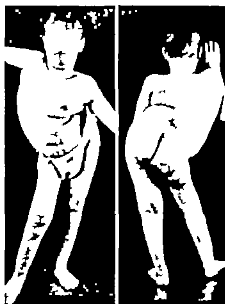


Fig 74 Paralytic scoliosis secondary to muscle imbalance above the pelvis (67)

scoliosis and by far the largest proportion of scolioses offer neither history nor clinical proof of poliomyelitis

Nervous System Diseases It is a fact that in some diseases of the nervous system notably Friedreich's ataxia (Fig 75) and spastic paralysis (Fig 76) scoliosis is often present In others, such as dystonia musculorum deformans (Fig 77) and spastic torticollis it is a less common but a very important part of the clinical picture Perhaps in many of these too, it is a question of muscle imbalance though none has been definitely recognized or established It is more likely however that the scoliosis in this group is truly neurogenic the result of a disturbance in the nerve supply and nutrition of the vertebrae or possibly of the epiphyseal plates. In many cases the age at which this type of scoliosis appears is the same as in the idiopathic type—between the sixth and tenth years

Rickets Rachitic scoliosis is diagnosed when a patient with structural scoliosis has multiple and unmistakable evidences of rickets (Fig 78) The scoliosis itself has no pathognomonic features, nor does it differ materially from other types of structural scoliosis Its one characteristic is that



Fig 75 Scoliosis secondary to Friedreich s ataxia

it tends to become severe earlier than other types The mechanism is probably the same as that of other rachitic deformities namely a metabolic or nutritional disturbance of the vertebral epiphyses and a resultant irregular and asymmetric development of the vertebrae aggravated by weight bearing The same explanation undoubtedly applies to the scoliosis seen in dyschondroplasia Morquio s disease (Fig 79) and similar systemic metabolic disturbances.

Unequal Length of Lower Limbs One limb may be shorter than the other (Fig 80) as a result of (*1*) joint disease, e.g tuberculosis of hip or knee or suppurative epiphysitis, (*2*) inflammation of the shaft of a long bone, as in osteomyelitis of the femur (*3*) injury, e g fracture of the femur or tibia with bowing or overlapping of the fragments (*4*) neuro-



FIG 79 Scoliosis secondary to spastic paralysis A Patient in upright position B Roentgenogram of spine

trophic influences, as after poliomyelitis Or one limb may be longer than its mate as the result of an equinus or a congenital or acquired hyper trophy

Such unequal length of limbs causes an obliquity of the pelvis and the spine in its effort to maintain normal balance acquires a scoliosis The lateral curvature may be present only when the individual is standing or walking and disappear in the sitting or recumbent position. Such a condi tion is frequently seen and should not be classed as a structural scoliosis The curve of the spine is not fixed it is a temporary physiologic compen

satory condition which disappears as soon as the tilt of the pelvis is corrected. When, as sometimes happens, the curve does become fixed, a structural scoliosis results. It is difficult to determine what factors in addition to the inequality of the legs will in some cases initiate and maintain a rigid curvature while other curves under seemingly similar conditions, will remain functional.

There is no doubt that in some cases scoliosis is caused by unequal length of the lower limbs. Of 40 patients with scoliosis whom I examined



Fig 77 Neurogenic scoliosis secondary to dystonia musculorum deformans

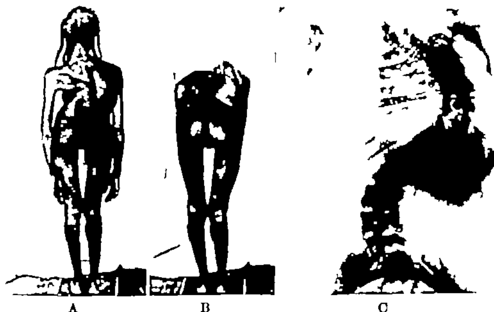
with particular attention to this factor one limb was shorter than the other by ½ to 1 inch in 7 (or 14.5 per cent) in all 7 patients the downward tilt of the pelvis was on the side of the shorter limb with a lumbar curve to that side. In another group of 110 patients, however only 8 had limbs of unequal length. If the left limb is shorter than the right the pelvis is tilted downward on the left side and the lumbar spine is curved to the left. In order to maintain the body in the erect position the dorsal spine curves to the right. In such cases we may properly speak of a primary lumbar and a secondary or compensatory dorsal curve. However by and large unequal length of lower limbs is an infrequent cause of structural scoliosis.

Torticollis Whether organic or functional this deformity of the head and neck is almost uniformly accompanied by a scoliosis (Fig 81). In the

early stages and for several years thereafter the scoliosis is of a compensatory and functional type However, if the abnormal state is allowed to persist throughout childhood and adolescence a structural scoliosis is a likely result

Thoracic Disease There are two varieties of scoliosis of thoracogenic origin that following disease of the pleura and lungs, and that resulting from thoracoplasty The former has been known for a long time the latter only since the introduction of extensive thoracic surgery

The typical scoliosis of the first type (Fig 82) is a severe thoracic or



A B C

Fig 78 Rachitic scoliosis A Patient in upright position B Patient in forward bent position C Roentgenogram of spine

cervicothoracic structural curvature secondary to a chronic empyema the convexity of the curve is toward the sound side of the thorax. The mechanism of this type of curve is relatively simple As a result of the infection the tissues on the diseased side become inflamed fibrotic, and contracted the resultant pull upon the upper and lower segments of the spine causes a curve which is concave on the diseased side and convex on the sound side In the exceptional cases in which there is a massive accumulation of fluid and a shift of the mediastinum the convexity is toward the diseased side The problem in this type of scoliosis is therefore purely one of mechanics.

Asymmetry of the trunk appears at first as an attitude assumed to relieve oneself of pain much as does the lateral tilt of the trunk in a sciatic scoliosis secondary to a derangement of the lower back. If uncorrected the

faulty posture in empyema persists and increases through the contraction of the intrathoracic soft tissues, and ultimately the faulty posture or functional scoliosis becomes converted into a structural scoliosis



A B

Fig 79 Scoliosis secondary to Morquio s disease

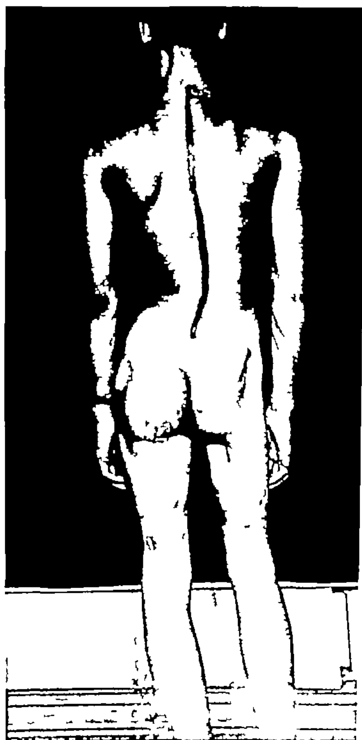


Fig 80 Scoliosis secondary to shortened limb





Fig 81 Scoliosis in infant secondary to congenital torticollis A Photograph B Roentgenogram of spine





A B

Fig 82 Scoliosis secondary to empyema A Patient in upright position B Roentgenogram of spine

In the deformity following empyema there is a shortening of the soft tissues an approximation and partial or extensive fusion of the ribs a limitation or absence of chest expansion on the contracted side and an overexpansion on the opposite side, a disturbance of the whole mechanism of pulmonary and chest function According to Bisgard (11, 12) a balance of opposing forces acting on the two sides of the vertebrae maintains the normal thoracic spine in a state of static equilibrium. The ribs muscles, ligaments and other soft tissues of the thoracic wall, as well as pleural intrapleural, and pulmonary pressures and stresses within the thorax all play a role and any appreciable imbalance in any of the factors is likely to produce a deviation The scoliosis resulting from an empyema always involves the dorsal and lower cervical vertebrae, except in the very severe cases in these the lumbar vertebrae form part of the thoracic curve or deviate in the opposite direction in a compensatory or balancing curve Generally the deviation is more marked than the rotation in severe cases, however rotation may combine with deviation to form a kyphoscoliosis.

Bisgard's statistics on this form of scoliosis are of interest Of 102 patients with acute empyema 44 had scoliosis, 38 were mild, 6 were moderate in 40 the convexity was *away* from the diseased side 3 had a massive effusion with the convexity of the curve *toward* the diseased side 1 had a pre-existing scoliosis 'Since the curvatures of acute empyema are produced mainly by muscle spasm" states Bisgard ' they usually correct themselves completely unless the disease progresses to chronicity " However the outcome in any scoliosis is uncertain and the effective treatment of an *acute empyema* should include *prevention* of asymmetric positions while the patient is in bed and during the early phase of convalescence when the patient is ambulant

Bisgard's statistics for chronic empyema are just as interesting Of 140 patients with chronic empyema, scoliosis developed in 95 the curvature was slight in 61 per cent moderate in 37 per cent and severe in 2 per cent in all but 2 the convexity was away from the diseased side in the 2 with the convexity toward the diseased side there was extensive pulmonary and pleural disease

In a series of 65 cases of empyema studied by Selig and Arnheim 1 to 5 years after operation clinical scoliosis was present in 5 of which 2 were severe One of the latter followed an extensive rib resection and the convexity of the curve was toward the operated side the other was a typical empyema scoliosis The other 3 all had mild curves.

Empyema is a condition which in the vast majority of cases comes to the attention of the general rather than the orthopaedic surgeon Nevertheless, early consultation with the latter seems a wise procedure for measures to prevent or control a possible scoliosis would then be proposed As

in other types of scoliosis, the greatest opportunity lies in the early start of preventive or therapeutic treatment Undoubtedly, the occurrence of scoliosis in empyema could be prevented by postural procedures to counter act the effects of the contractive forces on the diseased side

Among 180 patients with pulmonary tuberculosis, Bisgard found scoliosis in 17.8 per cent In all of them the dominant etiologic factor was a mechanical one the following being present (1) extensive parenchymatous fibrosis, and retraction of the thoracic wall, mediastinum and vertebral bodies,



Fig 83 Scoliosis secondary to left lobectomy (11) A Patient in upright position B Roentgenogram of spine

(2) extensive pleural involvement (3) massive atelectasis In 42 cases of bronchiectasis there were 5 with empyema and scoliosis (11 per cent), but only 1 case of scoliosis among the remaining 37 patients

Whatever the origin of this type of pleural scoliosis, it is apparently the early spasm and later contraction of all the tissues on the diseased side that initiate the curvature But in scoliosis following thoracoplasty the second type of thoracogenic scoliosis, the mechanism is quite different

Thoracoplasty has become a widely used procedure for intrathoracic disease and particularly for pulmonary tuberculosis When ribs are removed the spine tends to deviate in that direction presumably because the action of the contralateral intercostal and back muscles is now unopposed and there is loss of resistance in the costal wall (Fig 83) Several factors affect

the degree of curvature First the number of ribs removed, the more ribs, the greater is the space toward which the spine may deviate Second the site of the rib resection the higher the level of rib resection, the more likely is a scoliosis to appear Third the proximity of the rib resection to the spine If segments of the rib shafts only are removed the stability of the spine is not altered but if the proximal portions of the ribs (head and neck) are excised scoliosis is apt to develop Apparently in removing the heads and necks of the ribs, and incidentally destroying the costovertebral ligaments, the corresponding vertebrae are deprived of a direct support and are literally pushed into the newly created space by the intrathoracic forces. The results of a study which I carried out some time ago are interesting in this connection in a group of 100 thoracoplasties for pulmonary tuberculosis, scoliosis had developed only in patients with a resection of the proximal extremities of the ribs.

In a series of 131 thoracoplasties Bisgard found scoliosis in 45 per cent A pre-existing scoliosis on the operated side increased in 21 patients, or 16 per cent A pre-existing scoliosis with the convexity on the opposite side in 12 patients (9 per cent) was reduced In 5 cases a pre-existing single curve became an S curve Of the 131 thoracoplasties 101 were extrapleural and were done for pulmonary tuberculosis, 53 of the patients had straight spines before operation while the remaining 48 had a scoliosis After the operation only 2 of the 101 patients had straight spines, and these 2 were from the group with preoperative scoliosis. These figures are some indication of the hazard of thoracoplasty as far as scoliosis is concerned

The scoliosis following thoracoplasty varies from mild to severe with conspicuous rotation only in the severe cases In the mild forms, the rotation is apt to be slighter than in corresponding idiopathic curves. In the case of a pre-existing scoliosis if the convexity is toward the operated side the curve is very likely to increase In contrast if the convexity is to the opposite side the scoliosis may be reduced or entirely corrected

Spinal Disease Affections of the spine such as spondylitis deformans, fracture-dislocation, osteomalacia, syphilis, or tuberculosis, in which an asymmetry of one or more vertebrae is present may be complicated by scoliosis. The deformity is usually mild and of no great importance as compared to the gravity of the primary lesion

CHAPTER X

ETIOLOGY (*Continued*)

DISTURBED VERTEBRAL EPIPHYSEAL GROWTH

This potential etiologic factor in structural scoliosis is deliberately discussed in a separate chapter to give emphasis to its importance in the causation of some perhaps many scolioses and in appreciating its utilization for the reduction and possible future cure of scoliosis.

Epiphyses Versus Apophyses

The body of a vertebra has usually a single, sometimes a bilobed center of ossification within a cartilaginous base Calcification and ossification progress from this center until early puberty when the superior and inferior vertebral body plates appear These plates were formerly considered as epiphyses, and were and still are by some spoken of as epiphyseal plates which are responsible for the longitudinal and over all growth of the vertebral body In recent years histologic studies (102) have led to the belief that, to quote Nachlas and Borden (71A) "These show above and below the bony nucleus of the vertebral bodies, layers of cartilage that are morphologically like the growth plates in the epiphyses of the extremities These structures are believed to be true epiphyses and the growth of the vertebral body in height is attributed to them " At the February 1950 Convention of the American Academy of Orthopaedic Surgeons Dr Edgar Bick of New York in a scientific exhibit presented what he believed adequate histologic proof that a vertebral body acquired growth from the activity of the cartilage layers adjacent to the central ossific nucleus and not from the so-called "epiphyseal plates The real epiphysis of the vertebral body is located deep to the superior and inferior vertebral plates which he considers as apophyses and not epiphyses The differentiation between the vertebral epiphyses and apophyses is important of course but for our present purposes, is academic Of practical value to us in our present task is the realization that the tissue in the superior and inferior parts of the vertebral body is epiphyseal in nature and subject to the functional influences, stimulating and depressing which affect all epiphyses, namely infection trauma, pressure traction and so forth

By analogy with deformities in the long bones due to manifest disturbances in bone growth and from the experiences of Phemister and a host of other surgeons that the growth of a bone may be retarded or arrested temporarily or permanently by various surgical measures applied directly or indirectly to the epiphyseal plates, the assumption is justified that in

the degree of curvature First the number of ribs removed, the more ribs, the greater is the space toward which the spine may deviate. Second the site of the rib resection the higher the level of rib resection, the more likely is a scoliosis to appear Third, the proximity of the rib resection to the spine. If segments of the rib shafts only are removed the stability of the spine is not altered, but if the proximal portions of the ribs (head and neck) are excised scoliosis is apt to develop Apparently, in removing the heads and necks of the ribs and incidentally destroying the costovertebral ligaments the corresponding vertebrae are deprived of a direct support and are literally pushed into the newly created space by the intrathoracic forces. The results of a study which I carried out some time ago are interesting in this connection in a group of 100 thoracoplasties for pulmonary tuberculosis scoliosis had developed only in patients with a resection of the proximal extremities of the ribs

In a series of 131 thoracoplasties Bisgard found scoliosis in 45 per cent A pre-existing scoliosis on the operated side increased in 21 patients or 16 per cent A pre-existing scoliosis with the convexity on the opposite side in 12 patients (9 per cent) was reduced In 5 cases a pre-existing single curve became an S curve Of the 131 thoracoplasties 101 were extrapleural and were done for pulmonary tuberculosis, 53 of the patients had straight spines before operation while the remaining 48 had a scoliosis. After the operation only 2 of the 101 patients had straight spines, and these 2 were from the group with preoperative scoliosis These figures are some indication of the hazard of thoracoplasty as far as scoliosis is concerned

The scoliosis following thoracoplasty varies from mild to severe with conspicuous rotation only in the severe cases In the mild forms the rotation is apt to be slighter than in corresponding idiopathic curves. In the case of a pre-existing scoliosis if the convexity is toward the operated side the curve is very likely to increase in contrast if the convexity is to the opposite side the scoliosis may be reduced or entirely corrected.

Spinal Disease Affections of the spine such as spondylitis deformans fracture-dislocation osteomalacia, syphilis or tuberculosis, in which an asymmetry of one or more vertebrae is present may be complicated by scoliosis The deformity is usually mild and of no great importance as compared to the gravity of the primary lesion.

The scoliosis in this case apparently resulted from wedging of the lumbar vertebrae due to the greater inhibition of the growth of the lumbar vertebrae on the left side than on the right That this is not an idiopathic scoliosis occurring fortuitously in an irradiated spine the authors say ' It differs from the usual idiopathic scoliosis in several respects The isolated lumbar curve (itself a rare occurrence) exactly follows the field of radiation, and the wedging is directed to the irradiated side In addition to the inhibition of growth in the left half of the vertebral bodies, there is inhibition of growth in the left twelfth rib, the left lumbar transverse processes and the left ilium —all included in the field of radiation Moreover in ordinary or idiopathic scoliosis the wedging is maximal at the apex and diminishes gradually towards the ends of the curve In this radiation induced curvature, the wedging is uniform throughout the lumbar spine '

Elsewhere I have called attention to the fact that any circumstance that leads to asymmetrical development of the vertebrae (as in congenital vertebral malformation) may cause a structural scoliosis It is therefore understandable that localized irradiation of the lumbar vertebrae inhibited growth on the irradiated side caused unequal development and hence wedging of the vertebrae and produced a structural scoliosis.

Arkin (6) in an earlier article bases his theory of the mechanism and evolution of a structural scoliosis on the assumption of a unilateral disturbance in the physiology of the vertebral epiphyseal cartilages, and arrives at the conclusion that the deformation of the vertebrae is the result of an asymmetric disturbance of epiphyseal growth by pressure In the discussion of Arkin s paper, Risser states

In 1862 after work and dissection on the foot Hueter concluded that wherever there was not direct apposition of joint cartilaginous surfaces in the growing individuals there was an increase in the growth of epiphyseal bone Volkmann in 1882 clarified that law and applied it to scoliosis

Risser cites as an example the case of a 9-year-old boy with a thoracic curvature of the spine

The thoracic area had been fused previously leaving a residual thoracic curve without compensation in the lumbar area, and causing a list in the direction of the thoracic curve In order to overcome this deformity the spine was bent markedly against the thoracic curve creating a sharp compensatory curve in the thoracolumbar area, just below the thoracic fusion This permitted a marked separation of the vertebral bodies at the thoracolumbar area creating a compensatory convexity on this side Four years later with rapid vertebral growth the vertebral bodies had built up into the space created by the bending of the thoracolumbar curve again illustrating Hueter Volkmann s epiphyseal pressure rule

After giving other examples of seeming fragmentation of the epiphyseal cartilages resembling that seen in the upper femoral epiphysis in Legg

some instances the basis for a scoliotic deformity is unequal growth of the vertebrae as a result of a disturbed and unequal development of the epiphyses of the vertebral bodies Bisgard and Musselman (13) experimentally produced scoliosis in animals by unilateral removal of the "epiphyseal plates (which must have included the subjacent epiphyseal cartilage) of several vertebrae There was a unilateral arrest of vertebral growth and a resultant curvature with the convexity toward the unoperated side Haas (33A) has also produced scoliosis experimentally by unilateral interference with the growth of several vertebrae

Very recently Nachlas and Borden (71A) reported on the production of scoliosis in dogs by unilateral stapling of the lumbar vertebrae The prongs of the staples were inserted into the centers of the vertebral bodies so that there was no direct injury to the epiphyses Because of the unilateral compression of the operated vertebrae during the natural growth of the spine the operated vertebrae developed more on the side opposite the stapling and a scoliosis—a rotary lateral curvature—developed with the convexity away from the stapled side They went so far as to correct an experimental scoliosis produced originally by stapling by inserting a staple on the convex side of the scoliosis

The influence of unilateral retarded growth of the vertebral epiphyses on the production of scoliosis is reported in current literature under the title of radiation scoliosis Arkin and Simon (6A) produced scoliosis in rabbits by irradiation of the vertebrae asymmetrically The resulting unequal bone growth yielded wedging of the vertebral bodies with the lesser height toward the irradiated side A remarkable and convincing experience along this line lies in the report of a case of a radiation induced scoliosis in a child by Arkin et al. (6B)

The patient a 13 year-old girl was seen in November 1947 for a scoliosis which had developed gradually In August 1935 at the age of six months the girl was treated for multiple melanomata of the back. Her entire back was covered with nevi in which were developing coal black melanotic tumors Since these tumors metastasize only after puberty about twenty five of them were excised At the age of nineteen months there was discovered an enormous tumor in the left side of the abdomen which was diagnosed as a Wilms tumor (embryonal adenomyosarcoma) She was treated by preoperative irradiation a nephrectomy and postoperative irradiation The irradiation was unilateral—to the left side of the abdomen and lower back In 1944 a marked dorsolumbar scoliosis was noted The left lower extremity was shorter than the right In 1947 the patient was found to have a *right lumbar scoliosis* The lumbar vertebrae were wedge-shape. The left ilium was smaller than the right ilium and the left twelfth rib was smaller than the right twelfth rib

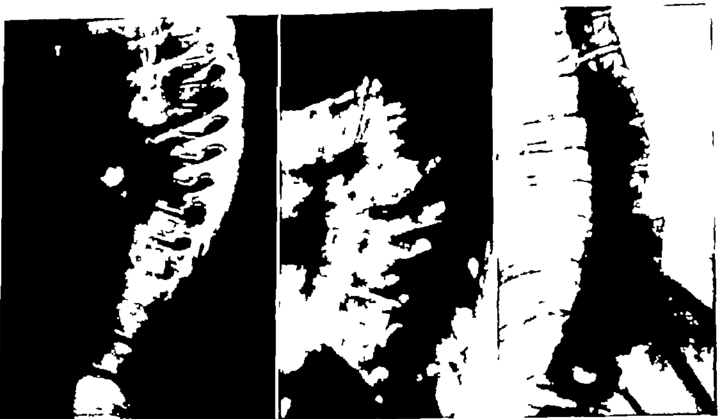


Fig 84 Roentgenograms of normal and scoliotic spines A Lateral view of normal spine outlines of vertebral bodies regular and sharply defined intervertebral spaces clear epiphyses visible anteriorly as thickenings B Scoliosis Lateral view of dorsal spine showing so called vertebral epiphysitis in early stage outlines of vertebral bodies irregular and indistinct intervertebral spaces diminished in size and irregular (involved vertebrae between arrows) C Anteroposterior view showing scoliotic spine secondary to vertebral epiphysitis B and C are of same patient

Perthes disease, Risser concludes that "not only are mechanical factors involved in the control of growth of bone, but also factors influencing bone physiology

Buchman's (16) observations are interesting in this connection. After studying the clinical and roentgenographic features in patients with scoliosis posterior curvature and other deformities of the spine he concluded that the majority of idiopathic scolioses are due to an affection of the superior and inferior vertebral epiphyses and that in many respects this resembles Koehler's disease, Legg Perthes disease and Osgood-Schlatter disease

Normally Buchman found the superior and inferior epiphyses (plates) (Fig 84A) of the vertebral bodies appear between the eleventh and twelfth years of life, and always first in the lower dorsal region. The epiphyses are thin plates thickened anteriorly and posteriorly, are well defined, and in the lateral view look like unbroken lines. The intervertebral disks appear as clear spaces, and adjacent ones are of about the same size The outlines of the vertebral bodies are sharply defined In idiopathic scoliosis however, the vertebral bodies and the disks presented a different picture (*1*) In some cases, the epiphyses appeared earlier than normal (*2*) The epiphyses were enlarged frayed rarefied fragmented unusually dense and irregular in shape (*3*) The intervertebral disks were mottled changed in size, and even obliterated. (*4*) The outlines of the vertebral bodies were indistinct irregular and at times indistinguishable (Fig 84B C)

In Buchman's opinion these pathologic changes constituted an affection or disease of the vertebrae which passed through a definite cycle lasted a variable time and led to a morphologic asymmetry of one or more vertebrae that produced a scoliotic deformity The changes occurred in about the following sequence First, the epiphyseal plates of the vertebral bodies become enlarged rarefied and frayed The disks then grow hazy mottled and indistinct after which the outlines of the vertebrae assume an irregular indistinct and moth-eaten appearance As the disease process advances, the epiphyses undergo fragmentation and change in shape and density the disks alter in size and become almost indistinguishable from the vertebral bodies and the outlines of the vertebral bodies are lost. Ultimately all differentiation between the epiphyses disks and bodies disappears, and there is an apparent fusion of many of the vertebrae Then follows a regression in the disease process gradually the outlines of the vertebral bodies can once more be seen the epiphyses (plates) become distinct, and the disks clear The disease is over but there remains a changed morphology and a deformity

Buchman found this affection of the vertebral epiphyses and adjacent

Vertebral Epiphysitis

Buchman's study is an important contribution to the problem of scoliosis. It is possible that the described changes in the vertebrae present a disease process or entity, and as such could be the cause of many cases of idiopathic scoliosis. However, this theory leaves unexplained the following facts (*1*) In many cases of so-called vertebral epiphysitis the result is a posterior curvature of the spine and only rarely a rotary lateral curvature (*2*) Unqualified changes in and at the vertebral epiphyseal areas, of a type and degree noted in so-called vertebral epiphysitis, are only occasionally encountered in structural scoliosis Nevertheless, the more one contemplates the initiation of different types of scoliosis the more emphasis is one inclined to place on the role of a disturbed growth of the vertebral epiphyseal cartilages from whatever cause as an important etiological factor in the production of structural scoliosis

An important outgrowth from the consideration of the epiphyseal origin of scoliosis is its application to treatment If unilateral disturbance of the epiphyseal vertebral cartilages will inhibit unilateral growth and cause scoliosis it can possibly be applied to the convex side of a scoliotic curve to inhibit or arrest the development of the vertebrae on that side, to effect an equalization in the shape of the wedge vertebrae and thus to correct or cure a scoliotic curve

Experimental scoliosis has thus far been produced by either unilateral epiphyseodesis or unilateral inhibition of growth by unilateral pressure as through stapling One case of experimental scoliosis has already been corrected by stapling on the convex side. It is but an additional step to so perfect the technic of vertebral growth inhibition that it may be effectively applied to reduce or correct the scoliotic spine in a child during the growing period

Heredity

It is generally believed that hereditary scoliosis (Fig 85) is uncommon, and that heredity is an unimportant etiologic factor But on the basis of my own experience I am convinced that this is not at all the case, and that inadequate attention to the history is the reason why it is so often missed. Actually hereditary scoliosis accounts for nearly 25 per cent of the cases In the strictest sense this scoliosis is idiopathic, since the factors which operate to perpetuate this familial defect are not yet understood In a series of 150 patients there were 35 that is 23.3 per cent with a history of two or more members of the family with scoliosis Father mother, brother, sister or some near paternal or maternal relative were discovered to be suffering from scoliosis It is common to find two or three members in a

structures, i e, a so-called vertebral epiphysitis, in many patients with posterior curvature of the spine, and in every case of idiopathic scoliosis diagnosed by himself No vertebral epiphysitis was found in spinal deformities of known etiology, such as tuberculosis, or in the normal vertebrae of a scoliotic spine On the basis of these findings, Buchman postulated that this affection is the cause of idiopathic scoliosis. As additional proof he cited a case which when first seen by him was clinically normal but with roentgenographic evidence of vertebral epiphysitis this patient later had a posterior curvature

The following is believed to be the sequence of events causing the osteochondral changes of so-called vertebral epiphysitis As a result of some infection such as tonsillitis, sinusitis or adenitis, there is an irritation of the epiphyses or an invasion of the vertebral epiphyses by minute emboli of avirulent organisms, resulting in multiple microscopic areas of necrosis. The epiphyses become weakened in spots. The superincumbent weight causes compression in the necrosed areas and uneven pressure generally over the epiphyses This results in unequal development and asymmetry of the epiphyses and hence of the vertebrae Axhausen (7 8) presented such a theory to explain Koehler's disease and there are numerous instances of bone deformity in Legg Perthes disease If such an explanation of this so-called disease process in the vertebrae is accepted one can also accept the hypothesis that so-called vertebral epiphysitis might be the cause of some or even of many cases of structural scoliosis.

Although the changes just described have been seen only in children between the ages of 10 and 15 years, it is more than likely that they start at a much earlier age they cannot be seen however until ossification of the vertebral plates makes roentgenography effective. My study of scoliosis has convinced me that although there may be no roentgenographic or clinical evidence in most instances this deformity starts before the tenth year when *the cartilaginous epiphyses are perhaps much more susceptible* to infection and certainly to the deforming influence of unequal pressure There are many examples of epiphyseal disturbance without evident roentgenographic changes. I have seen numerous cases of Osgood-Schlatter disease, for instance in which the pain tenderness, and swelling were marked but in which there was no recognizable roentgenographic evidence of pathologic changes in the tibial tubercles.

Calvé's (17) experience supports the possibility that disease of the vertebral epiphyses might be the cause of a spinal deformity He reported two cases of posterior angular deformity of the spine simulating Pott's disease In both cases there was a nonsuppurating lesion of a vertebra resembling Legg Perthes disease

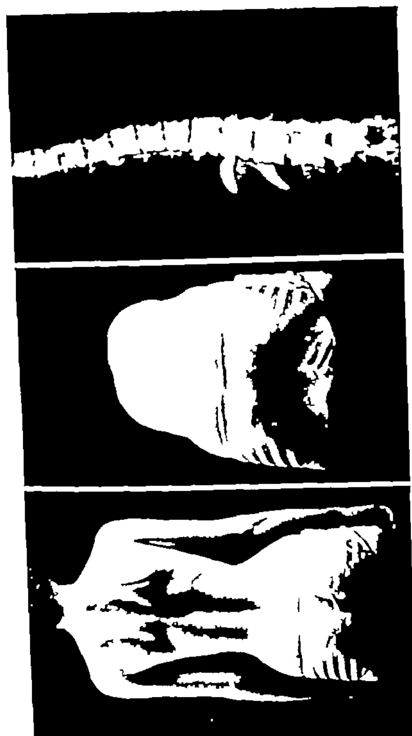


Fig 85 D F Scoliosis in the daughter



A B C

Fig 85 Hereditary scoliosis A–C Scoliosis in the mother



D F

Fig 85 D-F Scoliosis in the daughter

family to have scoliosis, and instances of six members with scoliosis are not unknown A noteworthy feature is the tendency for the same type and degree of scoliosis to predominate in a family At times other deformities especially rigid posterior curvature of the spine, have been discovered in a parent, uncle or grandparent

Such a high incidence of familial occurrence cannot be fortuitous There must be some factor in scoliosis which makes for transmission of this deformity Unfortunately, even when the fact is established that scoliosis may be hereditary, no clue is provided as to its pathogenesis. The assumption of a weakness or tendency in the germ plasm brings us once more to the "X factor In the study of the etiology of scoliosis, theory, hypothesis and imagination will continue to play their parts until an unequivocal answer is discovered, and the "X" factor is identified

Incidence of Scoliosis

Frequency

A lack of uniformity in standards renders difficult the determination of the relative frequency of scoliosis among orthopaedic conditions as a whole Those who include functional and structural scoliosis in their figures report a much higher percentage than others who include structural types only In some clinics, 30 per cent of the orthopaedic cases are listed as scoliosis, while in others the percentage is much smaller There is no doubt that among school children a large number perhaps 25 per cent show some form of functional curve or scoliosis In a clinic on the other hand to which children are brought for treatment the structural type forms the larger part of the cases of scoliosis In private practice, a relatively larger number of functional and mild structural scolioses are seen than in hospital work. No reliable data are available as to the incidence of scoliosis in the population as a whole

Sex

Functional scoliosis occurs with about equal frequency in either sex, as does structural scoliosis of known origin e g poliomyelitis, empyema, or congenital vertebral malformation The idiopathic variety that is to say the majority of structural scolioses is much more frequent in girls than in boys although the statistics on the proportionate frequency in the sexes vary widely Lovett (62) from a survey of the literature gives a range of 7 per cent to 25 per cent for boys and 74.8 per cent to 93 per cent for girls. In my own series of 1,390 hospital cases there were 419 males and 970 females, or 30 and 70 per cent respectively It is generally believed that the ratio of boys to girls is between 1 to 4 and 1 to 6

TABLE V

Age When Scoliosis First Recognized in a Series of 300 Cases

Age	No. of cases	Age	No. of cases	Age	No. of cases
yrs.		yrs.		yrs.	
Birth	7	19	2	41	0
Up to 3 mo	0	20	3	42	0
3-6 mo	5	21	2	43	1
6-9 mo	1	22	1	44	2
1	0	23	1	45	2
2	1	24	4	46	0
3	4	25	1	47	0
4	3	26	0	48	0
5	0	27	4	49	0
6	9	28	5	50	2
7	4	29	0	51	1
8	11	30	1	52	0
9	12	31	1	53	1
10	27	32	3	54	2
11	26	33	2	55	0
12	31	34	3	56	0
13	39	35	1	57	0
14	15	36	1	58	1
15	10	37	3	59	0
16	10	38	1	60	1
17	3	39	0	61	0
18	4	40	2	Unknown	12

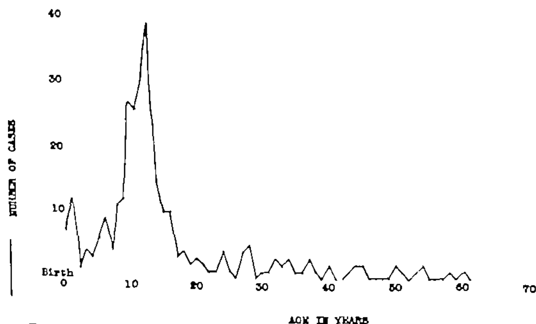


FIG 86 Graph showing ages at which scoliosis was first recognized with number of cases

Age of Onset

The exact time at which curvatures may appear is uncertain in view of the lack of close observation of a large enough group of children from infancy through adolescence, and the mildness of the early stages of scoliosis. The age when scoliosis was first recognized in a group of 300 patients is given in Table V and Figure 86 The largest number of cases in this series was in the group between the ages of 8 and 14 years. Since in every one of these cases the curvature was well established when first seen one is justified in assuming that it had been in existence for several years previously I conclude therefore, that structural scoliosis has its onset between the ages of six and ten years It is about this time, in point of fact that most children become independent and begin to bathe and dress alone so that their naked bodies may not be seen by parent or guardian for months at a time The possible development of scoliosis should therefore be kept in mind at all times and periodic physical examination particularly between the ages of six and ten years, should be considered essential. Frequent physical examination is particularly important in families with a history of scoliosis and should include roentgenograms of the spine in the recumbent and sitting or standing positions.

That much still remains to be done in the field of education of parents and teachers has only recently again been impressed upon me A 14-year old girl is at present (1950) a patient at the Hospital for Joint Diseases for treatment of a severe scoliosis which was first recognized only several months ago during a physical examination The deformity had manifestly been in existence for several years during which time its presence went undiscovered.

Chapter XI

HISTORY, SYMPTOMATOLOGY, EXAMINATION, RECORDS

In the treatment of scoliosis the fullest possible knowledge about the patient is of the greatest importance Family background, the patient s physical neurologic and psychic make up interests ambitions and social adjustment—all have their bearing on effective treatment

History

Family History

The fact that scoliosis may be hereditary makes scrupulous inquiry into that aspect of the family background mandatory Thus, questioning may reveal that the father has always had round shoulders, a sister has one shoulder higher than the other an aunt has a curvature and a cousin has a prominent "hip The type degree and progress of the familial scoliosis is of decided interest since the patient s curvature will be apt to follow the trend of the others. The presence of any organic nervous disease in the family may be significant such conditions as spastic paralysis and Fried reich s ataxia are complicated by scoliosis. Inquiry should also be directed to the occurrence of systemic disease among the members of the family

The mental and emotional atmosphere of the family should not be over looked Are the parents quiet stable cheerful people or are they sad, temperamental and given to emotional upset? Is the home life a happy cheerful and sane one with everybody working according to his age in terests, and ability or do the parents quarrel neglect their children or have no control over them? Unrest in the household lack of parental love and understanding absence of needful parental authority and a state of economic stress all militate against a concerted cooperative uninterrupted, and successful management of the patient On the other hand, loving parents and the child s confidence in his parents help to make treatment continuous and effective The presence of some one in the family who might urge the parents to consult one physician after another and thus create distrust dissention and harmful interruption of treatment perhaps at a moment when the spine has been mobilized constitutes one of the hazards in the control of scoliosis.

To be able to do the best for the patient, the surgeon must therefore have a thorough knowledge and as complete a picture as possible of the family and the family life

The family income is another point on which information should be obtained Scoliosis is a condition requiring treatment for many years—5 to 10 years or even longer in the case of a congenital scoliosis recognized in infancy Such prolonged treatment makes inroads on the family s financial means which are quite different from the demands of an acute short ill ness The surgeon well aware of the length of treatment should make it clear to the parents

Patient s History

This should go back to the birth of the patient if possible Was labor easy or difficult? Was it attended by any trauma to the infant? These and similar questions will bring out anything of significance in the patient s infancy Whatever data can be obtained with regard to the young child s health and habits—whether the child was robust or weak anemic or not illnesses and the time of their occurrence duration and severity and se quelae if any—all this tells much of the nature of the material so to speak that one will have to work with If a child has always been in good general condition has had few illnesses which have left no defects, if he is well developed well nourished and active the prognosis will be better than if the child were puny undersized pale and had had numerous enervating diseases. A history of poor muscular development and repeated exhausting diseases may explain a predisposition to faulty posture In some cases the history will point to the cause of the scoliosis, as, for example poliomyelitis, rickets empyema torticollis or Friedreich s ataxia

According to Lovett excessive height or weight or both is important as a rule decidedly overgrown children are less resistant to physical exer tion and seem particularly susceptible to defects of posture This factor is of growing importance at present in view of children s more rapid growth and greater height today In this relation one might bear in mind that the vertebral epiphyseal cartilages are especially vulnerable during the adoles cent period and may be so disturbed that an asymmetric development and a scoliosis ensue (Fig 87)

The patient s habits undoubtedly play an important role in the etiology and development of scoliosis but it is difficult to elicit information about them Parents are not always observant and children are usually unaware of habits that may be harmful Many children tend to assume constantly some abnormal posture while carrying books writing reading or in the course of other activities this if continued for any length of time and particularly by a child with a susceptible spine will lead to a curvature.

How long there has been awareness of the deformity and its progress are the next points of inquiry Any existing roentgenograms or photographs should be obtained for comparison with the new records If there is reliable



FIG 87 Scoliosis due to excessive height (boy 6 feet 3 inches in height)

evidence that the deformity has increased the scoliosis is probably one that steadily grows worse and therefore requires immediate and vigorous treatment On the other hand if the history and records reveal that the curvature has shown no tendency to increase for some time, active treatment may be deferred although observation must be continued.

The age of onset is an important factor the earlier the scoliosis appeared the more likely it is that the curvature will become severe. The initial cause and the deforming forces will have persisted for a longer time and there is greater opportunity for complicating factors, such as an exhausting or severe illness, to intervene

Symptomatology

Chief Complaint

In children this is likely to be any of the following high shoulder high "hip sunken waistline, prominent shoulder blade large breast It is not unusual for inequality of the "hips to be noticed first when a child is trying on new clothes Occasionally, an observant parent will notice the curvature of the spine Among the presenting complaints of older children and adults are deformity of the back, backache, pain in the neck weak legs, poor posture stiff gait, stiff shoulder, deformed chest fatigue stomach trouble palpitation and dyspnea.

In a group of 207 private patients, many of whom knew that they had scoliosis, the chief complaint was deformity of the back by 117 (57.5 per cent) and backache by 44 (21 per cent) In adolescent girls with well developed breasts and a moderate or severe deformity one breast appears much larger than the other in such cases parents usually fear disturbed growth and function

In children the chief complaints are in the order of their frequency (*1*) high 'hip (*2*) high shoulder (*3*) prominent breast (*4*) prominent shoulder blade (*5*) deformity of the back (*6*) fatigue (*7*) backache (*8*) pain in the chest, abdomen or legs (*9*) indigestion (*10*) dyspnea

General Symptoms

As a rule the general health of a child with scoliosis, from infancy to and including adolescence is good In the absence of some coexisting condition the child has good color feels well suffers little inconvenience can attend school regularly engage in all kinds of gymnastics, and stand the strain of additional studies such as music or dancing It is remarkable that even with extreme deformities the young patients often look and feel well

Exceptionally in the mild and moderate types and somewhat more often in the severe cases, the child will be below par physically showing

some degree of anemia an easy fatigability and a definite inability for strenuous physical activity Carrying a heavy load of books, climbing several flights of steps in school or at home, walking long distances physical play all may rapidly exhaust the child, with a resultant disinclination to exercise There may be loss of appetite and other signs of physical inadequacy In such instances there is great likelihood and danger that even mild and moderate curvatures will rapidly become aggravated (Fig 88)

A complaint of *pain* is rare in children particularly up to the age of 10 but not infrequent in adults the older the patient, the more likely is such a complaint Among 330 patients 93 (28 1 per cent) had pain The age distribution of back pain in this group may be seen in Figure 89 and Table VI

In the average case the pain is characterized as a mild backache, but in some the pain is constant severe and disabling. There are all gradations between these extremes depending on the severity of the deformity and the age and sensitivity of the patient Adolescents in jobs that require steady application to work for six to eight hours a day or for short periods of heavy work may suffer from backache and are often exhausted at the end of the day In severe scoliosis when the chest is greatly deformed or telescoped into the pelvis the pressure of the lower ribs against the iliac crest may cause pain. Referred or radicular pain in the limbs chest or abdomen occur in the severest deformities in which the intervertebral foramina are contracted and there is pressure on the nerve roots.

Dyspnea and tachycardia especially on exertion may be present with severe deformity in which the capacity of the chest is much reduced, occasionally too there may be symptoms of gastrointestinal disturbance But in general children have few complaints

Women with scoliosis in the fourth, fifth and sixth decades of life often complain of mild backache lumbar rather than dorsal and fatigability These patients are largely housewives who do all their own work The scolioses of some of these patients are mild and have been present since childhood or even since birth in some cases the patient has not even been aware of the presence of a scoliosis while in others no attention had been paid to it because in earlier years it had caused little or no discomfort

In adult patients with a rather persistent pain throughout the back radiating to the chest abdomen and even the extremities the scoliosis is one involving the dorsal and lumbar segments Fortunately, in such cases a spine fusion operation usually relieves the backache

Emotional Disturbances

Some adults with scoliosis are frankly neurotic complaining continuously of pains and aches, fatigue on slight exertion, and many bizarre and un

related symptoms although the scoliosis may not be severe Such patients are hard to treat satisfactorily Aside from this neurotic group most patients with scoliosis suffer some emotional disturbance particularly children from the age of puberty through adolescence.

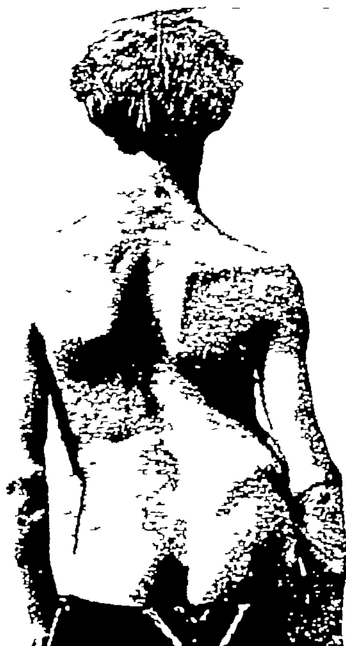


Fig 88 Left dorsal scoliosis due to occupation patient a grocery clerk carried heavy baskets supported on right iliac crest and acquired habit of holding body tilted to the left (80)

The psychic or emotional factor presents no particular problem in patients up to the age of 10 thereafter there is an increasing intensity of feeling which may persist throughout adult life The growing awareness of a physical distortion and the resultant self-consciousness does not affect everyone in the same way Some take their destiny and restrictions resign-

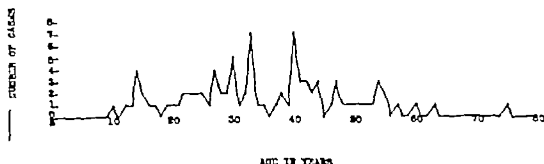


Fig 80 Graph showing incidence of back pain in structural scoliosis

TABLE VI

Relation Between Pain and Age in a Group of 93 Patients

Age	Number of cases
yrs.	
Birth–10	0
10–20	12
20–30	10
30–40	21
40–50	24
50–60	10
60–70	2
70–80	1
Unknown	4
Total	93

edly and do not fuss with themselves or those about them whereas others yield to a sense of inferiority and defeatism and become resentful and vindictive venting their splenic attitude on parents comrades and physician

Examination

For close observation and appraisal of the various details relating to the deformity the body should be completely unclothed down to the level of the great trochanters If the patient is an adolescent girl an apron may be suspended from the neck in front

General Condition

The patient s general condition is noted first development color musculature state of nutrition appearance of anemia height and weight as compared to normal Rate of respiration, pulse, degree of chest expansion and vital capacity come next The presence of associated conditions, such as rickets flat feet, torticollis imperfect vision or hearing a shortened limb is looked for and recorded with care Heart and lungs are examined thoroughly

Trunk Posterior View

With the patient standing with back to the physician the position of the trunk is noted i e whether directly over the pelvis or inclined to right or left The position of the spine is observed closely, its deviation being indicated by the line of the spinous processes This is best done by erecting a perpendicular line from the cleft between the buttocks and noting the site direction and extent of the spinal deviation from this line (Fig 90) It should be noted whether the deviation involves part or all of the spine whether it is all to one side of the perpendicular line or whether it shifts from one side to the other at various levels Prominence of one side of the back should be looked for and noted as well as that of the shoulders The position of the scapulae is observed (*1*) are they on the same level or is one higher than the other (*2*) what is the distance of the scapulae from the line of the spinous processes and from the arbitrary midline? Rotation of either scapula may be present The presence or absence of any asymmetry and of hollowness or prominence of either side of the back chest or lumbar region is noted The waistline may be exaggerated on one side and reduced or obliterated on the other One iliac crest may be more prominent than the other this finding should be correlated with the curve of the spine. The position of the head is important it should be noted whether the head is in the midline or to the left or right of the mid line The outlines of the neck should be carefully looked at, involvement of the cervical vertebrae will make one side of the neck more conspicuous than the other The position and inclination of the pelvis must be observed in most cases the pelvis retains its anatomic relation to the trunk and lower limbs the change if present is usually a downward inclination on the convex side of the lumbar curve and may amount to a tilt of 5 to 15 degrees

Trunk Posterior View Forward-bent Position

With the back about horizontal and the arms hanging down a rotation deformity if there is one becomes evident because of the backward projection of one or another part of the back (Fig 91) The extent degree

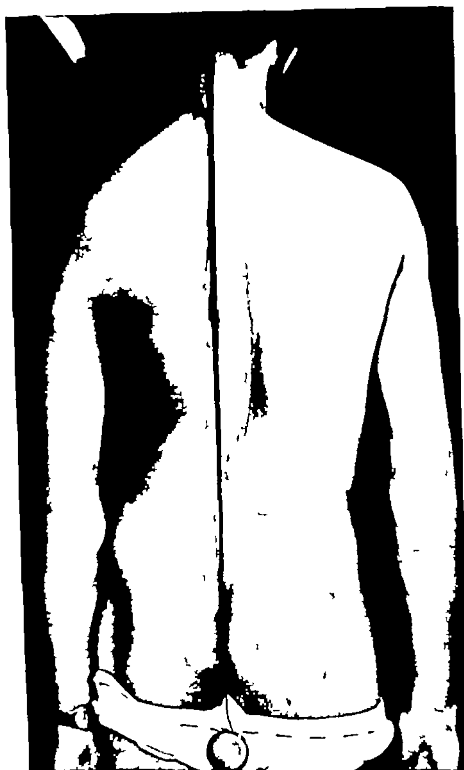


FIG 90 Scoliotic patient in upright position plumb line in internatal fold lateral deflection of trunk and deviation of spine

and location of the rib prominence is noted, it indicates the presence of a vertebral rotation deformity, and therefore a fixed curvature Rotation deformity varies from mild in which the prominence is only a slightly rounded one to severe with a marked angular projection of the ribs. This deformity is much more evident in the thoracic than in the cervical or lumbar regions because of the accompanying deformity of the ribs.

In mild curvatures, and in well-developed or fat children a rotation deformity may not be evident when the patient is in the erect position Since this deformity is an indication that the scoliosis is fixed or structural in character it is essential that its presence or absence be ascertained. The position of flexion i e the forward bent position is the best one for dis-



FIG 91 Scoliotic patient in forward bent position showing rotation deformity and asymmetry of back.

covering rotation deformity since even in the mildest cases this position *will reveal the asymmetry of the back No examination of a suspected* case of scoliosis is therefore complete without examination of the back in the forward bent position

Trunk Anterior View

The following must be looked for and recorded (Fig 92) (*1*) Nature and extent of any asymmetry of the chest and abdomen shape of chest which side of chest is prominent or flattened position and direction of sternum (*2*) Level of shoulders (*3*) Shape of thorax in axillary region whether compressed and flattened or rounded and bulging (*4*) Level of the anterior superior iliac spinous processes this indicates any abnormal tilt of the pelvis. (*5*) Curve of the waistline and any changes from the normal

Spinal Mobility and Potential Correction of Scoliosis

The degree of mobility, as pointed out by Lovett, is almost an exact index of the degree of correction that may be achieved through treatment The first step therefore, is to determine the degree of voluntary or passive correction of which the spine is capable The more mobile the spine, the



Fig 92 Anterior view of scoliotic patient showing asymmetry of trunk

easier will it be to improve the deformity A fixed rotation deformity indicates structural changes in the vertebrae and it is these changes which are responsible for the limitation of motion of the vertebrae and of the spine as a whole The more severe the rotation the greater is the rotation deformity, the more marked the structural changes in the vertebrae and the external configuration of the trunk and the more limited the mobility of the spine

There are several tests for the flexibility of the spine and the degree of correction that may be anticipated (1) The patient is asked to assume voluntarily a better or more normal position this allows one to judge the degree to which he may voluntarily reduce the deformity (2) The patient is then asked to lie down in the prone position, and the reduction in the deformity and asymmetry of the back is noted (3) With the patient in the erect position his hips and shoulders are securely held or fixed by an assistant while the physician by means of manual lateral pressure on the chest, ascertains the degree and facility with which correction may be made (4) The patient is suspended by a head sling and the reduction of deformity effected thereby is noted

If the asymmetry of the back is markedly reduced during these tests, and the line of the spinous processes is straightened and brought nearer to the midline the prognosis is good If the curve is only slightly or not at all altered and the rotation deformity is unchanged the prognosis is not encouraging

Length of Lower Limbs

The limbs must be measured carefully If there is any inequality in their length, it must be correlated with the distribution of the curvature

Records

Clinical Records

The written description of the findings of the physical examination is only one part of the essential record in scoliosis The photographic and roentgenographic visualization of the deformity is equally important A great deal has been written on methods for the accurate measurement and graphic recording of the type and degree of spinal curvature For my part I have for some time been convinced that there is neither need for nor practical value in mathematically accurate methods of mensuration What is needed is a reasonably and approximately accurate record by means of photographs and roentgenograms of the deformity of the back and the curvature of the spine so that one need not rely solely on one s memory

I should like to stress at this point that since scoliosis is, for the present at least not curable the result to be sought and obtained is not a change so minute that it is discoverable only by measurement with complex ap-

paratus, but gross improvement which family as well as physician can see I will therefore describe a single method of photography which can be used repeatedly under similar and standard conditions and thus provide comparable photographs for evaluating progress Roentgenography, too, can be carried out under standard and always similar conditions The angle of each curve is then measured and recorded An estimate of the degree of scoliosis in terms of angles of curvature is accurate enough for practical purposes.

Photography

Photographs of the patient in different postures provide a good clue to the type and character of the deformity Two posterior views—one in the erect position another in the forward-bent position with the arms hanging down—are essential Anterior and lateral views will be found helpful but are not indispensable The distance between patient and camera should be noted, in order to have subsequent pictures taken under the same conditions.

Photographs are much less reliable records than roentgenograms, a chance and unwitting elevation of one shoulder or a twist of the body or some peculiarity of lighting may result in a deceptive appearance For example if during treatment of a right dorsal curvature with a marked hollow of the back on the left the trunk is rotated to the left, a photograph would seem to show that a marked improvement had taken place the asymmetry being apparently reduced actually however, there may be no change in the spine Nevertheless, when combined with roentgenography and the record of the clinical examination photographs are useful

The following rules for photographing a scoliotic patient are taken from Lovett (62)

1 The patient must stand at ease with the legs straight and the arms hanging at the sides in a relaxed position 3 The patient must stand at a fixed distance from the camera in all cases if pictures are to be used as accurate records 4 The light should be oblique from behind preferably diffused and not the direct light of the sky if possible which gives too violent contrasts between light and shadow A light from overhead throws the shadow of the shoulders onto the back and obscures the spinal furrow A light directly from behind gives a flat white picture without contours A light directly from the side throws the shaded part of the body into such blackness that the body outline of that side is lost A crossed light obliterates contour and gives a flat and confusing picture 5 The shadow should be diminished by a white reflector on the side of the patient away from the light By this arrangement contour may be secured in the picture 6 The unsteadiness and swaying of the patient may be obviated in a measure by placing an ordinary photographer's rest against the chest

The frame devised by Bucholz and Osgood (15) for standard photographic records of scoliosis is a simple apparatus and gives fairly accurate

results. The apparatus may also be employed in taking roentgenograms thus standardizing the roentgenographic records

Roentgenography

The roentgenogram is an invaluable aid in the study of the spine A clear roentgenogram reveals with a good deal of accuracy the degree of deviation and the rotation deformity that may exist A series of roentgenograms should be taken—a large one of the entire spine, including the pelvis if possible, and several small ones of the different sections of the spine, this permits detailed study Such a series of roentgenograms permits one to see

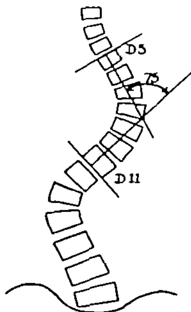


Fig 93 Measurement of the angle of the curve (20)

not only the general curve of the spine but also the degree of rotation of the different vertebrae the conformation of each vertebra, the shape and size of the different parts of the vertebrae (bodies, articular processes spinous processes intervertebral disks) the presence shape, and size of a hemivertebra the number size inclination and shape of malformed ribs and the presence of wedge-shaped or other types of vertebrae Often clinical examination will show only a moderate rotation of the vertebrae whereas the roentgenogram will reveal marked rotation Malformation of the sacrum sacralization of a lumbar vertebra, a deformity of the pelvis and other conditions not recognizable by clinical examination are disclosed in a roentgenogram.

An adequate roentgenogram while it may not tell the whole story is probably the best single record of a scoliosis Taken under standard condi

tions at different times, roentgenograms do much to obviate differences and errors in individual judgement, and enable one to estimate any increase or decrease of deformity Simple visual comparison of roentgenograms made at stated intervals is often enough to tell whether a case is making favorable progress is static, or is growing worse

For the sake of the record however, it is advisable to measure the various



FIG 94 Measurement of rotation (20) A Normal vertebra no rotation B Rotation

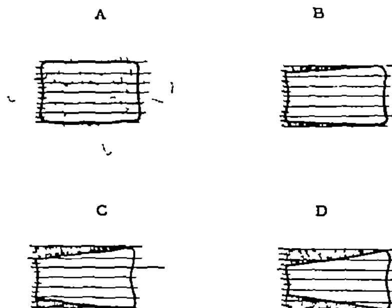


FIG 95 Determination of degree of wedging of vertebra (20)

elements of the deformity, especially the angle of the curve. The following procedure is quoted from Cobb (20)

I Locate the top vertebra (D5 [on Fig 93] in this case) The top vertebra of the curve is the highest one whose superior surface tilts to the *side of* the concavity of the curve to be measured (The superior surface of the vertebra above it usually tilts in the opposite direction to the side of the convexity but may be parallel The intervertebral space on the concave side is usually wider above the top vertebra and narrower below it but if there is vertebral wedging *this I V* space may vary)

II Locate the bottom vertebra (D11 in this case) The bottom vertebra is the lowest one whose inferior surface tilts to the side of the concavity of the curve to

results. The apparatus may also be employed in taking roentgenograms, thus standardizing the roentgenographic records.

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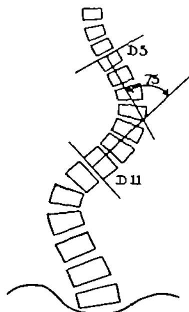


FIG 93 Measurement of the angle of the curve (20)

not only the general curve of the spine but also the degree of rotation of the different vertebrae the conformation of each vertebra the shape and size of the different parts of the vertebrae (bodies, articular processes, spinous processes, intervertebral disks) the presence shape and size of a hemivertebra the number size inclination and shape of malformed ribs and the presence of wedge-shaped or other types of vertebrae Often clinical examination will show only a moderate rotation of the vertebrae, whereas the roentgenogram will reveal marked rotation. Malformation of the sacrum sacralization of a lumbar vertebra a deformity of the pelvis, and other conditions not recognizable by clinical examination are disclosed in a roentgenogram.

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PART II

Treatment

A good orthopaedic surgeon is one who has unlimited patience and optimism

Virgil P Gibney

be measured (The inferior surface of the vertebra below it usually tilts in the opposite direction to the side of the convexity but may be parallel The I V space on the concave side is usually wider below the bottom vertebra and narrower above it but if there is vertebral wedging this I V space may vary)

III Erect intersecting perpendiculars from the superior surface of the top and the inferior surface of the bottom vertebrae of the curve

IV The angle formed by these perpendiculars is the angle of the curve "

With regard to the evaluation of the curve's angle The Research Committee of the American Orthopaedic Association (5) had the following to say in its report on scoliosis, in 1941

A measure of the severity of the curve was obtained by determining the end or neutral vertebra on either extreme These were taken to be the ones showing the least rotation with the interspace approximately equal on either side A line was then drawn parallel with the top of the upper-end vertebra and one parallel with the bottom of the lower-end vertebra and a perpendicular erected to each of these lines The angle of deviation from the normal (180 degrees) was then measured at the intersection of these two perpendicular lines

It is rarely necessary to measure the degree of rotation and wedging but for the sake of completeness it will be described

Normally, the spinous process is seen approximately in the middle of the vertebra. If the spinous process is to the left of the midline the right articulation to the left of the right border of the vertebral body and the left articulation poorly or not at all seen the vertebra is rotated to the right opposite findings indicate rotation of the vertebra to the left In order to measure rotation Cobb divides the vertebral body into six segments, as shown in Figure 94A Cobb s scale for degree of rotation (Fig 94B) is 1 plus rotation if spinous process is at *b* 2 plus if spinous process is at *c*, 3 plus if spinous process is at *d* and 4 plus if spinous process is beyond *d*

The normal vertebral body is a quadrilateral with the lateral measurements equal At the apex of a scoliotic curve the vertebral body is wedge shaped with the base of the wedge on the convex side The degree of wedging can be judged satisfactorily according to Cobb by dividing the body of the vertebra horizontally into six parts (Fig 95A) His scale for measuring wedging is 1 plus wedging if 0 to $\frac{1}{6}$ of height of vertebra is involved (Fig 95B) 2 plus if $\frac{1}{6}$ to $\frac{1}{3}$ of height of vertebra is involved (Fig 95C) 3 plus wedging if $\frac{1}{3}$ to $\frac{1}{2}$ of height of vertebra is involved (Fig 95D) and 4 plus if more than $\frac{1}{2}$ of height of vertebra is involved

While mathematic precision in the measurement of the various elements in a scoliosis is impossible because of many variables, nor needed for a general evaluation of the results of therapy a practical simple method of recording the deformity is helpful in guiding the surgeon during the course of treatment I believe the procedures described in this chapter especially the one for estimating the angle of the curve amply answer the need.

CHAPTER VII

PREVENTIVE TREATMENT

In planning a therapeutic procedure in a case of scoliosis, the physician must keep in mind not only the etiology, pathology, and type and degree of curvature, but also the age, the social and economic status of the patient, the patient's emotional character, and many other factors The effect of treatment on the spine alone cannot be the sole guide in deciding upon the course of treatment For instance treatment may result in a roentgenographic reduction of the spinal deformity, but in the process the chest may become terribly distorted and the heart and lungs may become terribly embarrassed in their function Or the patient may be subjected to unnecessary suffering by a treatment pursued so vigorously that large, festering painful pressure sores occur In view of the great courage which many patients with scoliosis possess, wisdom dictates that therapeutic enthusiasm must be tempered by careful evaluation of the possible benefit from the proposed treatment Moreover since a cure is not yet attainable, logic dictates that the simplest method be selected which will yield reasonably good results. With the above facts in mind I propose to discuss first the prophylaxis in scoliosis, and then the treatment of the functional and structural types of scoliosis separately

Prophylaxis in the majority of cases of scoliosis is a difficult problem for the deformity appears insidiously and is frequently idiopathic But in a minority (about 30 per cent) in whom there are definite etiologic factors which can be more or less controlled vigorous measures can be instituted that may prevent or at least limit the development of a scoliosis

PREVENTION IN SPECIFIC CONDITIONS

Poliomyelitis

Muscle imbalance is assumed to be the chief cause of scoliosis following poliomyelitis. Such imbalance operates in the recumbent as well as in the upright position, and a scoliosis may appear in a bed-ridden patient, however the upright position through the pull of the force of gravity, aggravates the effects of muscle imbalance and unquestionably increases the curvature The major problem then is to reduce the ill effects of muscle imbalance to a minimum by keeping the patient in bed until there is substantial recovery from the muscle paralysis

When the lower limbs are not extensively involved or when the patient is recovering the use of the back and leg muscles there is often such anxiety to see the child sit up stand and walk that little or no heed is paid to the

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When the lower limbs are not extensively involved or when the patient is recovering the use of the back and leg muscles there is often such anxiety to see the child sit up stand, and walk that little or no heed is paid to the

back. An inclination of the body to one side or the other during standing is attributed merely to "weak" muscles, and it is assumed that as the child becomes stronger it will support its body normally This is an unfortunate error, for the asymmetry of the trunk is a sign of physical deficiency, a paresis of some of the muscles of the back, abdomen or pelvifemoral group which may lead to an eventual scoliosis. It is better to err by keeping the patient in the recumbent position too long than by hastening assumption of weight bearing During convalescence, the patient should be kept on a rigid, flat bed or a slightly convex frame of the type used for Pott's disease, in exceptional cases if the abdominal muscles are affected a position of *slight flexion is the best A plaster bed (see Fig 143) is a very convenient* device for keeping older patients in a normal position. Only when the lower limbs have so far recovered that it is reasonably certain that the child can stand without assistance should the strength of the back muscles be tested Not until the child can raise his chest while lying prone so that the back remains symmetric and can raise himself unaided from the recumbent position should he be permitted to sit up for short periods The back should be repeatedly examined, clinically and roentgenographically while the child is sitting up If while in this position the body sags the back is asymmetric, and the spine deviates laterally or curves backward abnormally the muscles are still weak and unable to support the trunk in the erect position further *recumbency together with appropriate treatment such as massage and* muscle training must be insisted upon even though it may entail many months of continued recumbency

If a curvature appears only when the child is standing the cause must be sought in some condition of the lower limbs Usually there is a shortening of a leg or contraction at the hip or knee or an equinus deformity What ever the condition found it must be corrected immediately by appropriate measures. The important point to remember is that weight bearing should not be permitted until the muscles of the back and abdomen have recovered and can support the trunk, and it is evident that there is no deformity of the legs When the legs are hopelessly paralyzed the patient may sit up as *soon as there is evidence of sufficient recovery in the trunk* muscles. Or, if circumstances are such that sitting seems not only desirable but expedient, a carefully prepared external support such as a celluloid corset or a spinal brace should be provided and the back frequently examined

Neurogenic Scoliosis

If the spinal curvature is recognized in its incipiency its progress may be arrested by a variety of orthopaedic measures, ranging from a simple corset to a spine-fusion operation

Rickets

Like the paralytic type, this scoliosis tends to become severe, hence, the back of a child known to have rickets must be examined at frequent intervals not only clinically but roentgenographically Obviously, the metabolic disturbance will be treated by diet, vitamins and heliotherapy It may be advisable to keep a rachitic child in bed preferably on a convex frame, until the acute symptoms have subsided, the sensitivity of the joints has disappeared, the musculature has improved and the spine remains in the midline By that time the risk that an asymmetry of the back will appear in the upright position is slight Should even the mildest scoliosis be discovered vigorous and continued treatment must be started at once to prevent increase of the deformity A program of watchful waiting is unsafe

If a mild rachitic scoliosis shows even slight changes for the worse, the patient should be put to bed preferably in a supportive apparatus like a plaster-of Paris bed If there are further signs of aggravation or if the patient is unwilling to remain in the recumbent position, a spine fusion should be performed on the major curve or in the case of an S curve with two equal portions, fusion in both segments

Habitual Faulty Posture

Muscle imbalance unequal intrathoracic pressure, and unequal tension or stresses on the vertebral epiphyseal cartilages are all strong potential causes of scoliosis. Habitually faulty posture, by initiating and maintaining unequal pressure and tension on the vertebral epiphyses can be responsible for some and perhaps for many of the so-called idiopathic scolioses

The causes for faulty posture in children are numerous reading writing, or carrying books in awkward body postures, violin or piano playing, mental and physical fatigue—to mention but a few Parents and teachers must therefore be on the alert to recognize faulty posture ferret out the causes and correct them

Improperly designed *school furniture* may result in faulty posture Chairs and desks should conform to the anatomic outline of the trunk in the sitting posture and be adjustable to the size and height of the individual As far as possible the various sections of the chairs and desks should be movable and various sizes should be available so that they may be adjusted to the needs of the individual child The chair and desk must be made to fit the child and not as frequently happens the child be compelled to adjust himself as best he can to the seating unit assigned to him.

A prime factor in comfortable sitting is the proper height of the seat from the floor so that the feet rest on the floor without strain This can

be accomplished by having chairs of different sizes, varying in width and height The individual seat could be adjusted to the correct level by some such device as screws in the legs of the chair which would permit additional elevation of 1 to 2 inches.

The back of the seat should be hollowed out for the fleshy part of the buttocks, and the front (about three-fifths of the total area) should be concave laterally as well as from in front backward, to conform to the shape of the thighs The width of the seat should be slightly greater than the measurement between the trochanters There should be an upward tilt in front, at about an angle of 5 degrees with the horizontal plane, for added comfort in sitting In depth the seat should extend to the upper border of the popliteal space and no farther The proper height width, and depth of the seat its slight upward inclination and the hollows for the thighs are all adaptations to the normal conformation of the buttocks and thighs, preventing abnormal pressure on blood vessels and nerves.

The back of the chair should have two crossbars or slats the lower one convex from above downward and from side to side so as to conform to the hollow of the lumbar region and its height regulated so that it comes in contact with the lower lumbar spine This bar should be movable vertically in order to allow for adjustment at the proper level The forward curve of this bar is of the utmost importance, for in order to sit comfortably the child is forced to maintain the normal lumbar lordosis and as a result sits up straight holding the trunk erect, the shoulders back, the chest high and the abdomen retracted In this erect posture the sacral region and the upper part of the buttocks curve backward, hence the space between the lower bar and the seat should be left open permitting free accommodation of the buttocks and the sacrum. The upper or dorsal slat must be concave forward to fit the convexity of the dorsal region and should be at the level of the lower angles of the scapulas Thus, the forward convexity of the lower bar and the concavity of the upper one give support to the back and remind the child to sit erect.

Whether the desk is a separate unit or attached to the seat it must not interfere with the freedom of the legs or knees Attached or free it must be movable up and down so that it may be adjusted to the correct height, and must also be movable forward and backward The top of the desk should slope toward the body at an angle of about 15 degrees with the floor this makes writing possible with the body in the erect posture and without strain The angle of inclination should be adjustable, to meet individual requirements and the lighting arrangements of the room

Adjustability of both chair and desk forms the basis of the proper seating arrangement The combination described encourages in fact it compels, habitual correct posture for the normal erect posture is the most

comfortable one to assume in it, and faulty posture would be readily noticed and recognized

Physical Causes

Whatever the cause of an *inequality of limb length* in a child, it must be promptly corrected and compensated Scoliosis develops in only a few chil

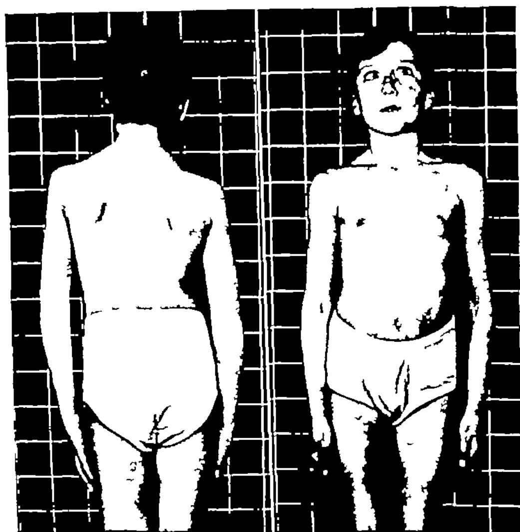


Fig 96 Scoliosis secondary to impaired vision

dren with a shortened leg but there is no way of foretelling in which instance a structural scoliosis will develop and in which it will not

Impaired vision or hearing (Fig 96), which tends to aggravate faulty posture should be rectified or compensated as early as possible for a spontaneous cure in these conditions is unlikely

Torticollis offers a splendid opportunity to prevent the development of a spinal curvature by correcting the condition. There is no spontaneous

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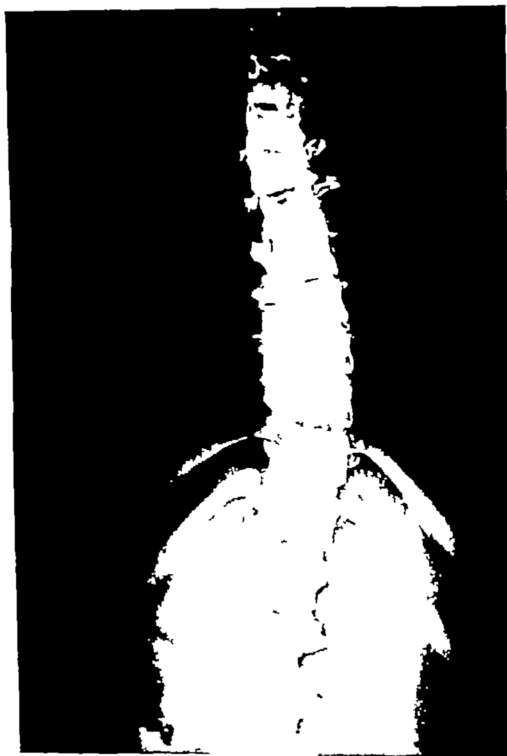


Fig 97 Scoliosis secondary to chronic heart disease

correction of a real torticollis, when congenital and accompanied by a marked shortening of the sternocleidomastoid muscle and underdevelopment and atrophy of one side of the face and skull, it will never right itself since there is a basic structural defect. Spontaneous correction of a torticollis due to birth injury and a hematoma in the sternocleidomastoid muscle may occur as the hematoma is absorbed But even in these cases it is safer to treat the child with massage, manipulation, and corrective apparatus, in order to assure a complete cure and thus prevent a scoliosis.

The type of *heart disease* (Fig 97) likely to initiate a scoliosis is one in which there is a marked enlargement of the heart, with or without decompensation. The role of the orthopaedist in such conditions is a secondary one and consists largely in providing supporting apparatus to the back when indicated Obviously strenuous treatment such as forcible correction is contraindicated Prevention of scoliosis depends upon the early recognition of both the cardiac and spinal conditions, and the close therapeutic cooperation between the internist and the orthopaedist

Empyema

A curvature may be prevented by early effective surgery administration of antibiotics chemotherapy, sedatives to diminish pain avoidance of an asymmetric position of the trunk while the child is in bed and provision of a mechanical support for the back and spine to counteract the pull of the contracting tissues on the diseased side Constant vigilance and scrupulous care are essential it may require special nursing but any price paid in service is worth while if a scoliosis is prevented As soon as the pleural infection is under control breathing exercises, controlled gymnastic activity for the muscles of the chest back, and abdomen and possibly a corset or brace will help to prevent a structural scoliosis

Hereditary Scoliosis

Like other forms, this scoliosis appears during early childhood begins as a mild deformity and tends to follow the pattern of the deformity in the family By discovering this type of scoliosis in its incipiency it may be possible to influence its otherwise natural progress to greater severity by the use of vigorous therapeutic measures

GENERAL MEASURES OF PREVENTION

As was shown in Chapter V scoliosis begins in most cases between the sixth and tenth years and usually develops for a number of years before a physician is consulted A number of factors militate against early discovery and these are in my opinion as follows (*1*) Parents or guardians

The present tendency to assign physicians and nurses to watch over the health of school children is a welcome one, and has doubtless permitted the discovery of many early cases of scoliosis But much can be done to make this health supervision even more effective The physician should not be expected to examine so many children at a time that the examination must perforce be perfunctory Nor are all school administrators fully aware of the importance of such periodic physical examinations, and therefore they fail to allow adequate time in the curriculum for them In some schools girls may not undress for physical examination without the specific consent of parent or guardian Such restrictions, since they prevent accurate observation of the child at a crucial age should be abolished Too much emphasis cannot be placed on the importance value and desirability of careful regular and frequent examination of all school children with sufficient clothing removed to permit observation of the bare back

Prevention is an important element in the management of scoliosis. The following program is recommended as one likely to yield gratifying results.

(*1*) Correct any and all faulty postures.

(*2*) Correct visual and auditory defects.

(*3*) Correct torticollis.

(*4*) Maintain symmetric posture in empyema patients

(*5*) Avoid improper seating arrangements in school and at home

(*6*) Postpone weight bearing and the upright position in the post-poliomyelitic period allowing sufficient time for adequate muscle recovery and until there is no tendency to trunk asymmetry In the presence of manifest irreversible muscle imbalance in the trunk, use a corrective spinal support, fascial reinforcement of the abdominal wall or spinal fusion any or all of them as required

(*7*) Postpone unrestricted activity during convalescence from an exhausting illness until physical recovery is complete

(*8*) Avoid prolonged and uninterrupted physical and mental strain in children.

(*9*) Advise against marriage of two persons, both of whom have scoliosis.

(*10*) Insist upon periodic physical examination of all children but particularly of those below the age of puberty and of those in families with a history of scoliosis.

(*11*) Direct a comprehensive program of education. This is probably the most important measure and should include all medical students pediatricians in postgraduate courses, parents and all teachers of young children

are, as a rule, unable to recognise spinal curvature (*2*) In stout children a mild curvature is readily overlooked because of the fat on the back particularly when the child is in the erect posture (see Fig 98) (*3*) When children begin to bathe and dress themselves, their naked bodies may be unobserved for months at a time It is thus possible for the deformity to progress until there is difficulty in fitting clothing or until it becomes so marked that it is conspicuous

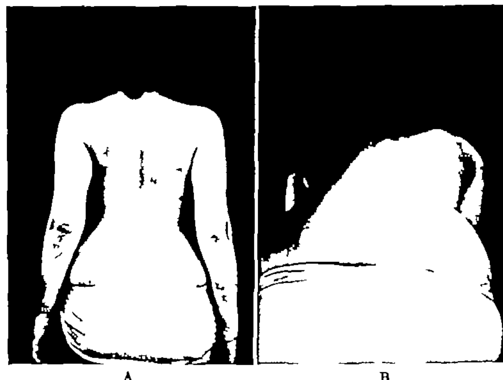


Fig 98 Asymmetry of back revealed in forward bent position A Patient in upright position no deformity visible B Patient bent forward note asymmetry of back.

Since in most instances persistent treatment will prevent a mild curvature from progressing all efforts must be bent to discovering scoliosis in its incipient stage I suggest the following routine as the most effective way to accomplish this. (*1*) An educational campaign to teach the public including school teachers, as to the nature causes course, and results of structural scoliosis (*2*) Examination of all children but especially those between the ages of 6 and 10 years at frequent regular intervals. Such examination must include inspection of the back minus all clothing and must include both the upright and the forward bent positions. It is in the latter position that rotation deformity of the spine becomes evident by the upward projection of one side of the back (Fig 98)

advantage of supervised exercises is that the instructor will recognize and correct faulty posture during exercises, while a patient exercising alone may have difficulty in doing so Supervision is particularly necessary for younger children, conscientious adolescent children and adults may be allowed to carry on alone, after they have thoroughly learned the exercises and performed them accurately for some weeks under supervision

The indications for the use of corrective exercises in functional scoliosis are (1) Patient over 10 years of age (2) Absence of cardiac or nervous organic disease (3) Ability to perform the necessary exercises without exhaustion or undue fatigue Children under 10 years of age are rarely able to concentrate sufficiently to profit by the exercises

The contraindications to the use of corrective exercises in functional scoliosis are (1) Youth of patient (under 10 years) (2) Patient of asthenic type (3) Presence of cardiac or nervous organic disease (4) Patient recovering from exhausting illness

The type vigor and length of each exercise period must be regulated according to the patient's ability to perform the exercises A thorough knowledge of the patient's constitution and the possible presence of any abnormal condition (anemia, heart disease, etc) is essential Exercises should be performed daily or every other day and each session should last from ½ hour to 1½ hours. The average child exercising on alternate days will need about a month to develop sufficient strength and endurance to work for half an hour without excessive fatigue

When the flexibility of the spine is limited to any extent, it is helpful to combine the exercises with passive stretching This may be done by manipulation, with the patient lying prone or supine on a table or with the patient suspended either by the arms from rings or a bar, or in a head sling

Most patients with functional scoliosis (school children high school and college students) are indifferent to their faulty posture and considerable tact and persuasion are required to impress them with the importance and the value of the corrective exercises It is up to the instructor to make the exercises interesting and acceptable in addition to being corrective

Supportive Apparatus

Patients with a tendency to revert to a faulty posture in the intervals between exercises may be benefitted by wearing some light supportive apparatus for a time In its simplest form the apparatus may consist of two shoulder straps attached to each other in such fashion as to remind the patient constantly to maintain the erect posture A celluloid plaster of Paris or whalebone reinforced canvas corset is the usual type of support

CHAPTER VIII

TREATMENT OF FUNCTIONAL AND TRANSITIONAL SCOLIOSES

FUNCTIONAL SCOLIOSIS

Essentially, a functional scoliosis is no more than a faulty posture unaccompanied by any structural changes in the bones and soft parts. Postural scoliosis occurs in both atonic and in sthenic children. The former are thin and pale, have a weak musculature, drooping shoulders, a prominent abdomen and weak feet. As a rule, they have poor appetite and are always in a relaxed and abnormal posture of one kind or another. Such children may have suffered a number of exhausting illnesses, although I have seen some who had had little illness and came of sturdy stock. The sthenic children, on the other hand, have a well-developed musculature and good color, look, feel and eat well, but through habit assume an improper posture.

The program for treating functional scoliosis calls for (*1*) removal of all manifest causes; (*2*) improvement of muscle tone by means of gymnastic exercises and thereby acquirement of the habit of normal posture; (*3*) temporary support of the trunk by some type of light apparatus if necessary.

Removal of Evident Causes

This calls for careful study of the patient and the elimination of any physical or other condition which is accompanied by asymmetry of the trunk. An anemia must be corrected by appropriate medication. Mental and physical fatigue can be overcome by sufficient sleep and plenty of fresh air supplemented with sedatives if necessary. Specific physical defects should be completely rectified, and so on down the line of all correctible elements.

Improvement of Muscle Tone and Body Posture

In general the exercises (described in detail in Chapter X) are of two types: *developmental or symmetric and corrective or asymmetric. Usually* both kinds are used during the same session. The patient should perform the exercises before a mirror; this helps him to see the difference between faulty and correct positions. Supervised exercises are always more effective, for the presence of the instructor and the commands for performing the different exercises have an important disciplinary and stimulating effect, and serve to develop a feeling of responsibility in the patient. A further

posture, or compensation for them, (2) gymnastic exercises, (3) support of the back

Correction of any manifest causes of a faulty posture is as important in



FIG 90 Congenital hemivertebra (indicated by arrow)

this type of scoliosis as in the functional type and is accomplished as described earlier in this chapter

Corrective exercises may be used as adjuvant therapy but the surgeon must then see the patient oftener and observe him more closely than at any other time during the management of a scoliosis Exercises mobilize the spine stretch the tissues and increase the tone and strength of the muscles This may lead to improvement through the acquisition of stronger muscles and a sense of proper balance and correct body posture, but there

employed For a detailed description of this type of apparatus, see pages 200 and 201

Prognosis

In functional scoliosis the prognosis is extremely favorable A child with a mild left or right functional curvature round shoulders, generally poor posture, and awkward gait will in about six months or less become alert, and physically active, and will sit stand, and walk in a normal posture. To prevent possible recurrence of the curvature, the patient should be advised to keep on with the exercises for at least several years after correction has been attained

Transitional Scoliosis

A transitional scoliosis is one that has the characteristics of a functional scoliosis but may at any time acquire the features of a structural scoliosis. This type of scoliosis results either from a functional one, or is the earliest form of a structural scoliosis It is rarely recognized mainly I believe because its existence is not kept in mind And yet the time of its occurrence is *the* most fruitful period for effective treatment of a structural scoliosis. The first problem then, is to define the circumstances under which the presence of a transitional scoliosis must be suspected. The diagnostic criteria while not incontrovertible may be assumed to be as follows

(*1*) Age of patient between 6 and 10 years.

(*2*) Persistent presence of a functional scoliosis

(*3*) Appearance of a scoliosis in the upright position, and its absence in recumbency

(*4*) Presence of an S curve of the spine be it ever so mild

(*5*) Presence of an uncompensated congenital osseous anomaly of the vertebrae or ribs that is, a potential mechanical cause of scoliosis (Fig 99)

(*6*) Presence of a mild scoliosis in the upright position in a patient with a familial history of structural scoliosis, suggesting a hereditary or genetic tendency

(*7*) History of poliomyelitis in the patient

(*8*) Unequal length of legs

(*9*) Presence of a fixed pelvic obliquity as after poliomyelitis, congenital dislocation of the hip spastic paralysis, or dyschondroplasia

Once the diagnosis of transitional scoliosis is established vigorous and continuous treatment must be pursued until such time as there is reasonable certainty that the curvature is not structural or if it is, that it will remain mild

The treatment of a transitional scoliosis, has, like that of a functional scoliosis, three features, namely (*1*) removal of all evident causes of faulty

posture, or compensation for them, (2) gymnastic exercises, (3) support of the back

Correction of any manifest causes of a faulty posture is as important in



Fig 99 Congenital hemivertebra (indicated by arrow)

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is also the danger that it may lead to increasing deformity Continuous, critical supervision is therefore imperative.

Support of the back is a primary need in the scoliosis under discussion Probably the best lightest, and most readily tolerated support (the apparatus must hold the spine in the midline and retain the back in a symmetric position) is a celluloid corset (see Fig 127) This is made over a plaster-of Paris model of the back in which any asymmetry is corrected. The correction is checked by an anteroposterior roentgenogram of the spine through the corset Any residual deviation of the spine is overcome by appropriately placed felt pads in the corset A plaster-of Paris corset, a reinforced canvas corset like the one devised long ago by Michael Hoke or any of a variety of braces, all of which are variations on the Knight and the Taylor spinal supports, may be used I do not recommend the use of a brace in scoliosis because since its support depends upon an accurate and undeviating adjustment of many straps, the possibility is always present of inadequate or improper adjustment of the straps and consequent failure of the required support Moreover, the patient may loosen the straps and thus disturb reduce or even nullify the usefulness of the brace. Nor in my experience have reinforced canvas corsets proved as effective as the more rigid celluloid or plaster-of Paris corsets, the permanent shape outline and structure of which are entirely under the control of the surgeon.

Chapter IX

TREATMENT OF STRUCTURAL SCOLIOSIS

In the words of Sir Arthur Keith (50), "it is anatomy and physiology that are the surgeon's best guides to rational means of spinal treatment." They are not the only guides, however. Not only the type and degree of curvature must be considered but also the patient's age, social and economic status and emotional character. In other words the individual as a whole, as well as the physical deformity, must be carefully drawn into account. It goes without saying that the therapeutic program should be the mildest that will yield the optimum results.

In view of the fact that many adults are seen in whom the scoliosis has remained mild, a reasonable question might be why scoliosis in a child, when mild, should be treated at all. I would answer such a question as follows:

(1) There is no way of knowing which deformity will remain mild and which will grow severe.

(2) A mild scoliosis causes few inconveniences; hence one must attempt to keep the scoliosis mild.

(3) In the absence of treatment many scolioses progress from a mild stage to moderate and even severe deformity (Fig. 100), and patients with such deformities suffer much disability.

In my opinion, therefore, all cases of scoliosis, however mild, require treatment of one kind or another until the patient has reached the age of 15 or 16 years. I would most certainly not advise the parents of a child with a moderate or even with a mild structural scoliosis to do nothing and wait for a check-up 6 months hence. In the interval the scoliosis might increase and assume what may rightly be called a malignant character. Bick's (10) statement regarding this attitude of expectancy versus active treatment is very much to the point:

> This feeling of futility in all except severe cases may have the merit of integrity of purpose. Nevertheless its danger must be seriously considered from another viewpoint. Whether the present attitude of disparagement of non-operative treatment is merely the result of discouragement with past results and therefore expresses a passing stage, or whether it is what Dean Inge referred to as a *moratorium on research*, remains to be seen. To state, as do these writers, that only severe progressing cases require treatment and that cases with less than a certain angle of deviation should be left alone may satisfy the investigator but may not satisfy the victims of moderate scoliosis. Admission of a *present* dissatisfaction with treatment is only permissible if it does not lead to complacency. This is not quite the time to halt some three hundred years of an accumulative attempt to solve the intricate mechanical problem of early correction of scoliosis.

No case of structural scoliosis has thus far been cured, in the sense that a deformed back has been converted into a completely normal back. What, then are the objectives of treatment? They are (*1*) prevention of further increase of the deformity, (*2*) reduction of the curvature and (*3*) maintenance of the improvement These objectives must be kept in mind in evaluating the progress and results of therapy

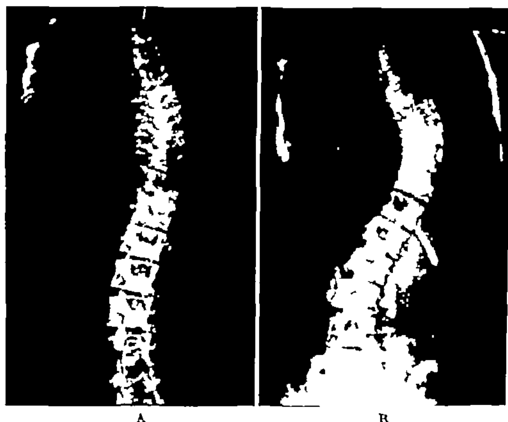


Fig 100 Roentgenograms of scoliotic spine A, Mild scoliosis B Same spine five years later severe scoliosis

With certain exceptions, scoliosis cannot be treated by applying corrective measures directly at the site of the major deformity namely the vertebrae All therapy therefore is indirect and attempts to improve the scoliosis by any several or all of the following means

(*1*) Overcoming the contractures of the soft tissues.

(*2*) Influencing the structure of the vertebrae and ribs by altering their function through a reversal of the posture of the trunk to one directly opposite to that of the deformity (Wolff's law)

(*3*) Modifying the growth of the vertebral bodies by altering the stress upon the vertebral epiphyseal cartilages through a change in

the attitude of the trunk and the direction and intensity of the forces of weight bearing (Hueter Volkmann rule)

(4) Mobilizing the spine and ribs

(5) Reducing correcting or overcorrecting the deformity by applying traction to the ends of the spine or traction or pressure at the apex of each curve

(6) Strengthening the musculature of the trunk and shoulder and pelvic girdles

The therapeutic measures by which the foregoing objectives may be accomplished comprise the following

(1) Gymnastic exercises

(2) Supportive apparatus

(3) Corrective apparatus

(4) Forcible correction

(5) Surgery

The most commonly used operative procedures are spine fusion and cosmetic rib resection Removal of a hemivertebra has been tried in a number of cases On occasion myotomy fasciotomy, or capsulotomy may be indicated and in the small number of cases in which paraplegia is a complication of scoliosis laminectomy is the treatment of choice The current venture into obtaining a reduction or cure of a structural scoliosis by selective inhibition of vertebral growth through stapling of the vertebral bodies at the apex of the curve was mentioned under etiology and will be discussed further in a later chapter

Prognosis

There are some mild cases congenital or otherwise which remain mild throughout the individual's life—that is an incontrovertible fact What we do not know is the percentage of the total that this group constitutes and what is responsible for the stationary character of these curvatures

Anyone with an even superficial acquaintance with scoliosis knows how often severe and unsightly scoliotic deformities are seen, all these were at one time mild and hardly noticeable, and became worse in the course of time Parents frequently state that their child's deformity was slight when it was first noticed and that it had gradually progressed In some instances to be sure, the deformity develops to only a moderate degree but since a rigid scoliosis, of whatever degree, will not get better without treatment this consideration in itself is sufficient reason for instituting treatment Furthermore even in the severe cases, in both children and adolescents, there is no assurance that the deformity will not grow worse Increase of a curvature has even occurred in adult life These considera

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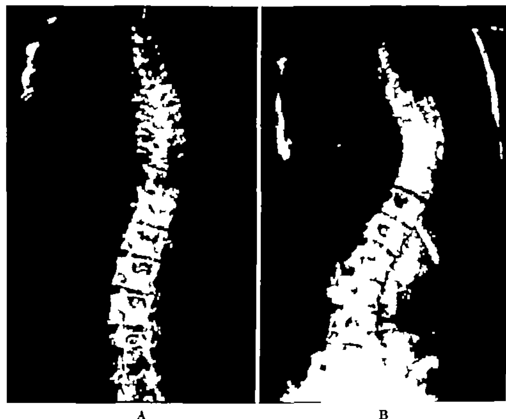


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tions lead me to state that an untreated scoliosis in a child or an adolescent has an uncertain and generally a poor prognosis In childhood and adolescence, a scoliosis, unless it is well compensated, is most likely to grow more severe

In contrast to the above evidence from all orthopaedic clinics where large numbers of patients with scoliosis are treated shows that conservative therapy is effective in the vast majority of cases. Increase of any given grade of scoliotic deformity can be prevented in 70 to 80 per cent of all cases by persistent and long-continued treatment and in about 50 per cent of these the curvature can actually be reduced It is of course evident that the earlier the treatment starts the better will be the prognosis, for a mild case will at least stay mild even if it is not improved. The term 'early' does not mean a case of scoliosis in a young child but the actual duration and degree of the deformity

The results of treatment depend chiefly upon the type of the deformity In the prognosis of a given case the following factors must be considered

(1) Duration of the deformity If for example a severe scoliosis has been present for 10 years, it is more than likely that the bones, muscles and ligaments have undergone marked secondary changes and very little improvement can be effected

(2) Part of the spine affected Practical experience has proved that with present methods of treatment very little improvement can be expected in a high dorsal or cervicodorsal curve whereas a dorsolumbar curve may be considerably reduced even in an adult

(3) Severity of the deformity The more marked the rotation deformity the more difficult it is to improve the appearance of the back

(4) Type of the deformity A single curve can usually be improved the more complicated the curve the harder it is to reduce it

(5) Congenital vertebral malformation In many cases, especially in those with multiple lesions on opposite sides of the spine the curves are well compensated and remain mild in the case of single lesions, such as hemivertebrae surgery may arrest the deformity and even offer hope of a cure

The prognosis in structural scoliosis with treatment may be summarised thus

(1) The very mild cases of rigid scoliosis can be satisfactorily treated by gymnastic exercises in combination with various spinal supports

(2) The moderate types of scoliosis can be markedly improved by conservative treatment in over 70 per cent of the cases, and in the majority can practically always be prevented from increasing

(3) The severe scoliosis can be somewhat improved by conservative treatment and may be prevented from becoming worse

(4) In 20 to 30 per cent of cases in which, for one reason or another, conservative treatment alone has failed, recourse to surgery (spine fusion, rib resection, etc.) will lead to improvement in the majority of cases.

(5) In a small group perhaps 2 to 5 per cent of the total number of cases in which no form of treatment stays the steady increase of the deformity, a marked scoliosis, with shortening of the trunk, great physical distortion of the trunk, and dysfunction of the internal organs is the end result

CHAPTER X

GYMNASTIC EXERCISES*

The use of gymnastic exercises for the treatment of scoliosis began so long ago that it is difficult to trace its origin In the course of the nineteenth century their use was popularized by Henry Ling in Sweden was amplified by orthopaedic surgeons in Germany and by the early 1900's was in extensive use in the United States.

As stated earlier the two kinds of gymnastic exercises used in the treatment of scoliosis are developmental or symmetric and corrective or asymmetric The first kind in which the muscles of both sides of the body are used simultaneously and to the same degree, is performed while the patient assumes the best possible position or the nearest approach to the normal position. The second type by which the muscles of one side of the body are developed more than those of the opposite side in the expectation that their hypertrophy and increased strength will hold the trunk in a corrected position involves the development of the muscles on the concave side of the back in single curves and the use of all the back muscles in compound curves The arrangement of the trunk muscles especially of the back where so many muscles overlap makes exercise of one muscle or group of muscles to the exclusion of all others impossible All the muscles of the trunk are exercised in such a manner as to produce an improvement in the external appearance of the back

In the first exercise period of 15 to 30 minutes the patient is taught the proper posture beginning with simple exercises using light dumbbells, Indian clubs and bell-bars Generally the patient is very tired by the end of this first period The work is gradually increased and the length of each session is extended but excessive fatigue must be avoided An increase in the respiratory rate and some acceleration of the pulse are usual but there should be no dyspnea or tachycardia. As the patient grows used to the exercises the periods may be increased to 2 or 3 a day each lasting 30 to 60 minutes. The exercises are beneficial only if each movement is performed forcibly and accurately Both developmental and corrective exercises are used during the same session the kind number and order depending on the judgement of the surgeon and the needs of the patient.

Extreme patience is essential in teaching exercises and it is best to work with one child at a time Every child must be observed carefully for his

* This chapter was written in collaboration with Dr Hans J Behrend of the department of Physical Medicine of the New York Hospital for Joint Diseases.

capabilities and peculiarities, an exercise which one child finds easy another may find difficult Progress is usually fairly rapid, patients with awkward postures, forward thrust head drooping shoulders prominent abdomen, easy fatigability, and unable to lift a dumbbell more than a few times in succession, frequently show remarkable improvement in a few weeks The older the patient, the more favorable is the result of gymnastic treatment The following results may be expected from such treatment

(1) Increased muscular strength
(2) Increased mobility of the spine
(3) Improved posture
(4) A tonic effect on the general condition of the patient

As a corrective agent in structural scoliosis, exercises are useful only for the *mildest types* of deformity, that is, those scolioses in which the change in the structure of the bones, ligaments, and other tissues is slight In such patients exercises reduce the deformity or at least so *improve the posture* that the deviation of the spine is barely evident Treatment and careful observation must be continued for a long time If there is no improvement in posture and the curve is not reduced, either the exercises are not being performed correctly or the scoliosis is already too severe for treatment by exercises alone

According to Lovett the only criterion of the efficacy of gymnastic treatment is progressive improvement A study by a Research Committee of the American Orthopaedic Association (5) published in 1941 found that the deformity increased in about 60 per cent of those treated by exercises and remained unchanged in 40 per cent Although some in the latter group might have remained mild without any treatment it is nevertheless encouraging that such a large number of cases can be prevented from increasing in severity

The increased mobility of the spine is usually a welcome result of the exercises, but in some cases may be harmful, for as the spine becomes more flexible the tendency to faulty posture and the pull of the force of gravity may increase the spinal curvature. Constant and scrupulous supervision is therefore imperative when scoliosis is being treated by exercises If the posture does not improve or the curve becomes more marked, other and more effective treatment must be undertaken.

The deformity in the *moderate* and *severe types* of structural scoliosis is not affected by gymnastic exercises, since they cannot undo the abnormal rotation and reshape the twisted and deformed vertebrae However they do form an important adjuvant treatment After a scoliosis has been improved exercises will help to maintain the spine in the improved position In patients with moderate scoliosis who will not submit to corrective

treatment exercises may help to prevent increase of the deformity by improving the posture and increasing the muscular strength.

Gymnastic exercises constitute an important therapeutic measure in scoliosis They are indicated not only in functional and transitional scoliosis but also in structural scoliosis under the following conditions

(1) In the mild type combined with supportive apparatus.

(2) In the moderate type, when the patient refuses other more effective treatment

(3) In the moderate type after the maximum potential improvement has been obtained by one of the conservative methods usually combined with supportive apparatus

(4) In the severe type in which moderate exercise gives a sense of well being

(5) After a spine fusion operation, gentle exercises will help to maintain good posture but they must be carefully selected in order to avoid mobilizing the fused area.

The exercises to be described constitute only a sample group Each physician can devise his own set of gymnastics, keeping in mind only that the main objective of gymnastic exercises is to acquire and maintain an improved posture

Exercises can be performed with or without apparatus It is sometimes advantageous to use dumbbells since they give one a sense of resistance which stimulates or is at least conducive to vigorous effort The use of Indian clubs and bell bars is similarly valuable as they provide interesting variety which tends to free exercises of an atmosphere of drudgery Exercises while always purposeful should also be made interesting and in their proper performance give the patient a sense of accomplishment Every exercise program begins with fundamental posture training Since body balance must be built up from the supporting base posture training must begin with teaching correct posture of the feet. The feet should be kept parallel two to three inches apart and the muscles of the inner arch should be tightened in the attempt to raise it The toes must be kept firmly on the ground The knees should be kept straight, the patellae pointing forward. Hyperextension must be avoided.

In order to maintain the center of gravity over the center of support, the pelvis must be in the correct position It is frequently found to be tilted forward increasing the lumbar lordosis. To correct this faulty posture the patient is taught to contract the abdominal muscles and those of the buttocks. The chest must be raised while the positions described so far are maintained The arms should hang over the lateral aspect of the hip joints. The chin should be taken in The patient is taught to raise the crown of the head as if in an attempt to reach the ceiling" (Fig 101)

Developmental or Symmetric Exercises

The following exercises are examples of symmetric exercises.

Exercise 1 Performed 20 to 50 times Arms fully extended downward,



Fig 101 Normal posture—the goal of the scoliotic patient

forearms supinated elbows remain close to the sides with upper arms thus fixed the forearms are alternately flexed and extended the wrists and entire body remaining fixed (Fig 102)

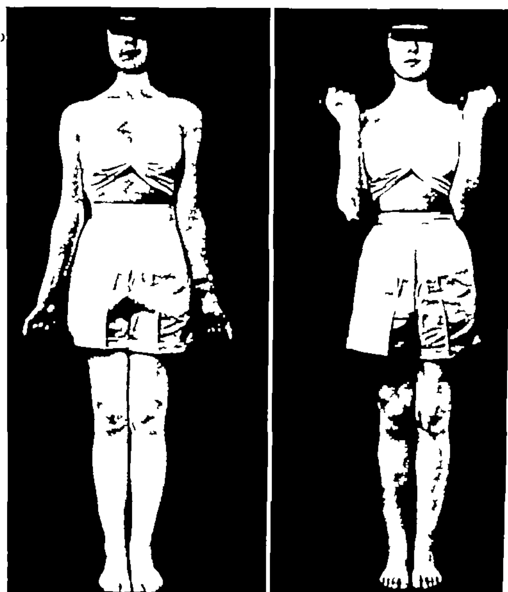


Fig 102 Exercise 1

Exercise 2 Performed 10 to 20 times. Both dumbbells over shoulders arms abducted at right angles to the body and in same vertical and horizontal planes, forearms fully flexed upon arms and wrists fully flexed upon forearms Both forearms and wrists are then alternately extended and flexed (Fig 103)

Exercise 3 Performed 10 to 20 times Same position as in Exercise 2 Arms are fully extended above the head and returned to original position (Fig 104)

Exercise 4 Performed 5 to 10 times Both arms fully extended forward on a level with shoulders the dorsum of the hand outward Arms are fully and forcibly abducted on a horizontal plane, the body being raised on the toes at the same time, arms are then permitted to recede to the original position, with body resting on toes and heels elbows and wrists

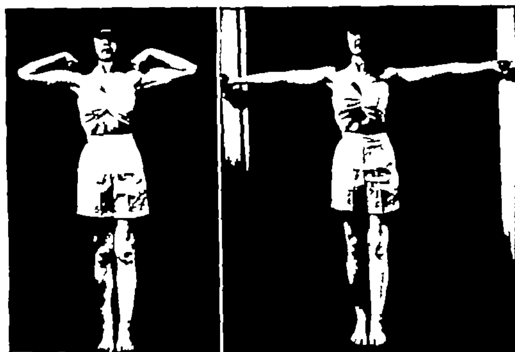


Fig 103 Exercise 2

still rigid, and the dumbbells not permitted to touch as they approximate each other (Fig 105)

Exercise 5 Performed 10 to 20 times. Dumbbells in front of thighs, forearms pronated Dumbbells are raised to level of shoulders and returned to original position

Exercise 6 Performed 5 to 15 times Extend bells above head palms forward bend down to the floor, knees remaining extended, and return to erect position (Fig 106)

Exercise 7 Performed 10 to 20 times With bells at the sides the spine is flexed laterally first to the right and then to the left (Fig 107)

Exercise 8 Performed 5 to 20 times. Both arms are extended at the elbows and abducted about 45 degrees They are forcibly crossed in front

of the chest, the elbows and wrists being fixed causing the pectoral muscles to contract vigorously, and then brought back to the original position (Fig 108)

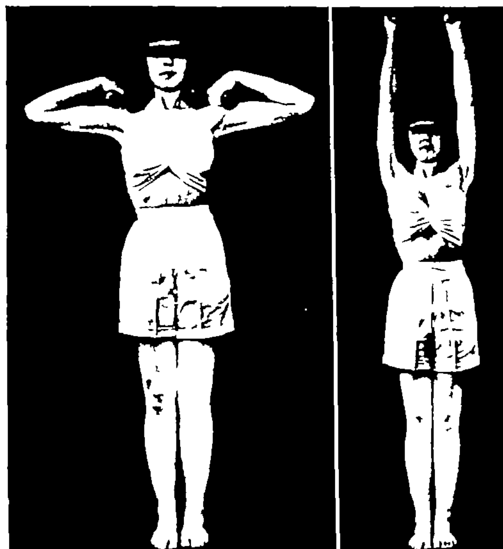


Fig 104 Exercise 8

Exercise 9 Performed 5 to 15 times Bells at the sides palms forward Both arms are extended backward in a vertical plane as forcibly as possible held rigid in the fully extended position for a few moments, and then returned to the original position (Fig 109)

Exercise 10 Performed 5 to 20 times. Bells at the sides. A squatting position is assumed resting upon the toes, heels raised knees separated trunk perfectly erect first position then resumed (Fig 110)

Exercise 11 Trunk twisting Performed 20 times In erect position with hands behind the neck, rise on toes, twist body slowly and forcibly to the right then back to the midline, then to the left and back again to the starting point.

Exercise 12 Deep breathing Performed 5 to 10 times. While instructor counts to 5 patient takes a deep breath, raises arms to a vertical position above the head and rises on tip-toes, during the following count to 5, the patient exhales, lowers arms, and resumes position on heels.



FIG 106 Exercise 4

Exercise 13 Thigh flexing and extending Performed 20 times each with right and left lower limbs In erect position hands behind neck, arms fully abducted Right lower limb is alternately flexed and extended Left lower limb is alternately flexed and extended (Fig 111)

Exercise 14 Thigh abduction. Performed 20 times each with right and left lower limbs Patient in same position as in Exercise 13 Right lower limb is forcibly abducted and brought back to neutral position Left lower limb is forcibly abducted and brought back to the original position

Exercise 15 Trunk forward bending Performed 10 times With hands on chest trunk is slowly bent forward until it is in a horizontal plane held there for a minute and slowly brought back to the erect position (Fig 112)

Exercise 16 Trunk stretching Performed 10 times 1 From the fundamental standing position the patient stretches the whole spine upward, breathing in 2 From the upward-stretched position the patient relaxes to the fundamental position, breathing out

Exercise 17 In the erect position with body held rigid patient swings

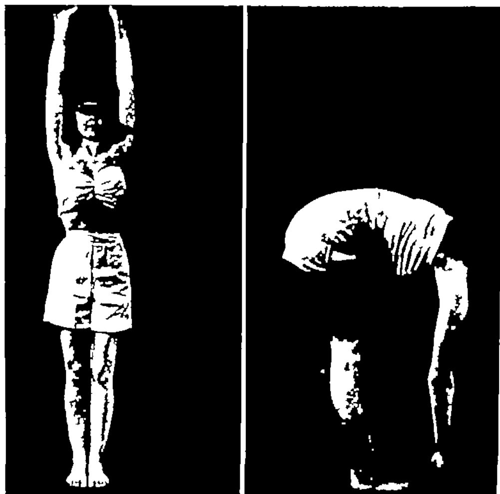


FIG 106 Exercise 6

a pair of 1 or 2-pound Indian clubs from in front backward 20 times, and as many times in the reverse direction. The latter motion is a particularly good one, for with each swing of the arms the body tends to straighten and the spine to become extended

Exercise 18 Performed 20 times In the erect position and holding the Indian clubs the arms are brought forward in front of the chest on a level with the shoulders, and alternately abducted and adducted

The following exercises are performed lying on the floor or on a table in the supine position

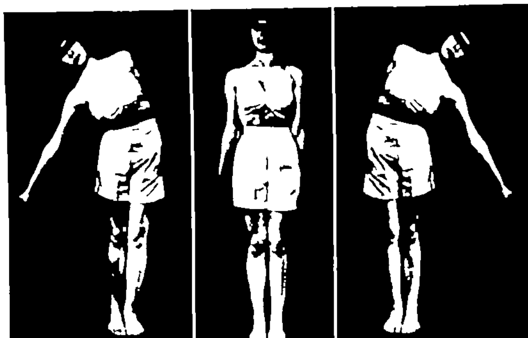


Fig 107 Exercise 7

Fig 108 Exercise 8

Exercise 16 Trunk stretching Performed 10 times. 1 From the fundamental standing position the patient stretches the whole spine upward, breathing in 2 From the upward-stretched position the patient relaxes to the fundamental position, breathing out

Exercise 17 In the erect position with body held rigid, patient swings

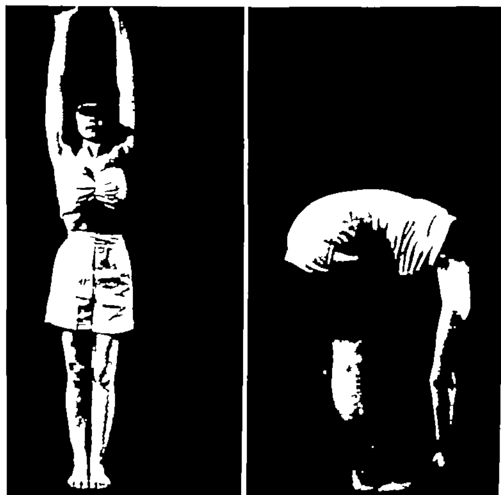


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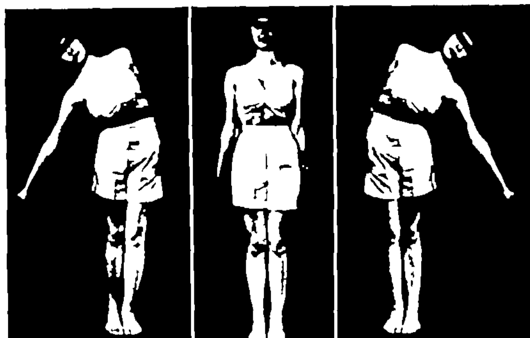


Fig 107 Exercise 7

Fig 108 Exercise 8

Exercise 19 Performed 10 times. Each lower limb, fully extended at the knee, is alternately lifted about two feet from the floor, then allowed to sink slowly to its original position.

Exercise 20 Performed 5 times Both lower limbs, fully extended at



Fig 100 Exercise 9

the knees, are lifted about two feet from the floor then allowed to sink back to their original position This motion exercises not only the muscles of the thighs but also the abdominal and back muscles.

Exercise 21 Kicking alternately with one lower limb Perform 20 times. Left knee flexed with foot on floor Flex right lower limb at the hip and knee forcibly extend knee and bring limb to the floor Reverse the procedure kicking with the left leg (Fig 113)

Exercise 22 Kicking Performed 10 times Both lower limbs are forcibly flexed at the hips and knees the knees are forcibly straightened, and the limbs are brought to the floor again



FIG 110 Exercise 10

Exercise 23 Flexion of the spine Performed 10 times The lower limbs are flexed on the abdomen with the knees separated and the hands clasped over the legs the head is then bent forward to the space between the knees return to original position flat on back This is a good exercise for mobilizing the spine

Exercise 24 Trunk raising to sitting position Performed 10 times. Patient rises slowly to sitting position, with spine stiff the patient then

sinks to the primary position, with the spine still stiff, the head touching the table before the back.

The following exercises are performed in the prone position.

Exercise 25 Performed 10 times With palms on hips patient looks at



Fig 111 Exercise 13

ceiling and hyperextends the spine then sinks slowly back to original prone position (Fig 114)

Exercise 26 Performed 10 times Each lower limb fully extended is alternately lifted upward as far as possible (hyperextension at the hips)

Exercise 27 Performed 5 times. Both lower limbs, fully extended are lifted upward as far as possible (hyperextension at both hips simultaneously)

Exercise 28 Performed 20 times With arms above head and thumbs hooked arms chest and lower limbs are lifted (Fig 115)

Exercise 29 Swimming exercise Performed 20 times With chest elevated patient to the count of 3 places hands on chest, extends arms above head and brings arms to the sides (Fig 116)

Exercise 30 Perform 20 times With arms above head and thumbs

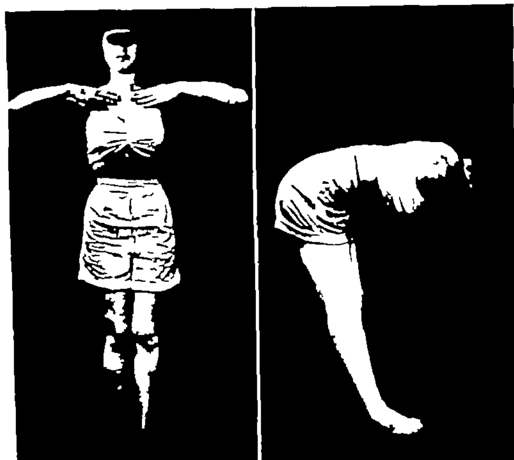


Fig 112 Exercise 15

hooked body is bent to the right, brought back to the midline then to the left and back to starting point

Exercise 31 Perform 20 times. With arms above head and thumbs hooked body is twisted first to the right then to the left.

Exercise 32 Chinning Performed 20 times. With the body held rigid and the palms on the floor near the chest the body is raised so that it rests on the toes and extended arms then elbows are bent and the body is brought back to original position (Fig 117)

Exercise 33 Performed 10 times. Lying prone with trunk projecting over end of table lower limbs resting on table and ankles secured by

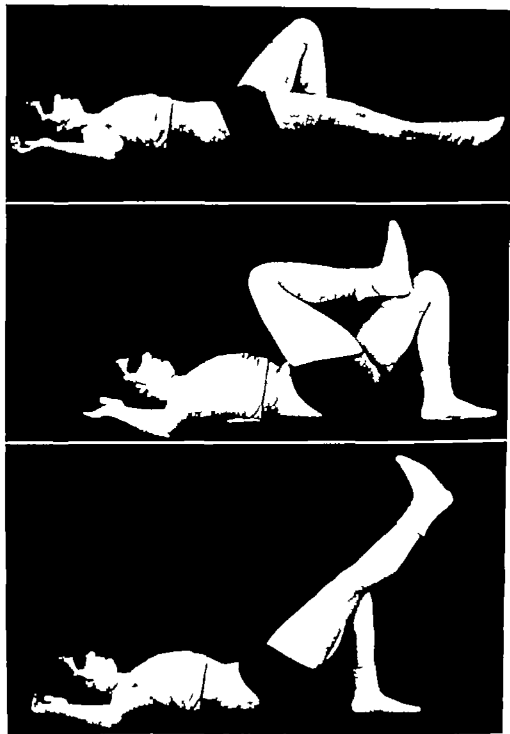


Fig. 113 Exercise 21

straps or by being held by instructor, body above the hip joints hangs over the table, head downward, hands behind neck with elbows squared (Fig 118) Patient inspires and raises trunk as far as possible by hyper



Fig 114 Exercise 25



Fig 115 Exercise 28

extending the hip joints and spine, then returns during expiration to original position

Exercise 34 Performed 20 times. Sitting astride a narrow table with hands behind the neck and the feet fastened by straps to the floor, patient bends forward until forehead touches the table then slowly bends back until back rests on table and finally rises to sitting position

Exercise 35 Position Sitting legs extended, arms abducted at shoulder level, feet dorsiflexed 1 Twist trunk to left bringing the right arm forward, left arm backward. Touch left toes with right hand Return to

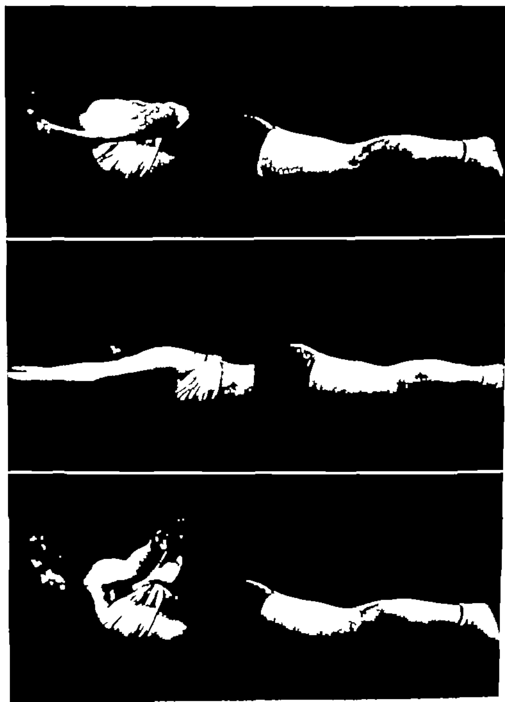


FIG 116 Exercise 20

original position 2 Repeat exercise but twist trunk to right, left hand touches right foot (Fig 119)

These exercises may be supplemented by the so-called "heavy work" advised by Teschner Dumbbells or bars weighing from 20 to 50 pounds may be used The use of these weights causes a marked increase in the



Fig 117 Exercise 32



Fig 118 Exercise 33

strength of the muscles. When a heavy bell is pushed or swung above the head on the side opposite the major curve the action of the back muscles in sustaining the weight and equilibrium is such as to cause the curved spine to approximate a straight line

Exercise 36 The patient swings a heavy dumbbell with one hand from the floor to above the head and down again with elbow and wrist fixed this is done 5 to 10 times The exercise is performed on the concave side of the curve and tends to straighten it

Exercise 37 Raising a heavy bar When a heavy bar is raised above the head with both hands, the patient must fix his eyes upon the middle of the bar to maintain his equilibrium. This necessitates bending the head

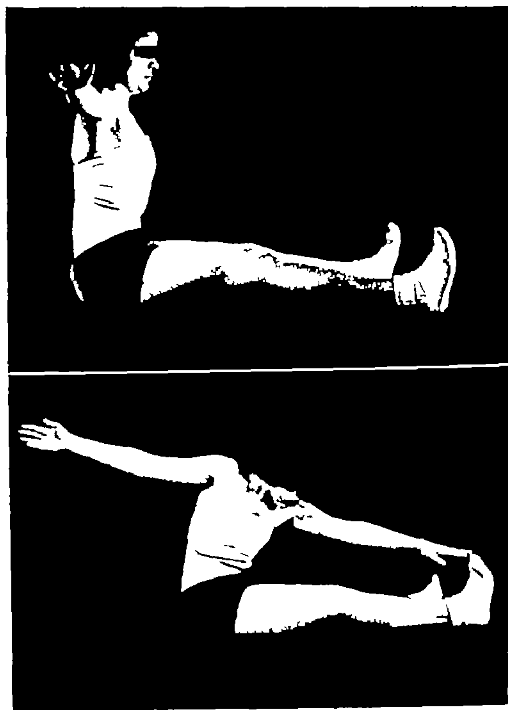


Fig 119 Exercise 35

backward, straightening and hyperextending the spine and thus correcting a faulty position with a weight superimposed The heavier the weight held above the head whether with one hand or with both, the more must the patient exert himself to attain and maintain an improved attitude

Corrective or Asymmetric Exercises

During these exercises the patient assumes postures in which the trunk appears more symmetric and the spine more nearly straight The motions in these exercises are planned to tax the muscles on the concave side, and



Fig 120 Exercise 40

to force these muscles to acquire increased strength by gradually increased work

Keynote Position Whenever possible exercises are performed in the keynote position In this position the patient depresses and retracts his high shoulder elevates the low shoulder and with the hand on the convex side pushes the chest in the opposite direction this tends to straighten the curve of the spine In a right dorsal curve for instance the left arm is elevated to a vertical position and the hand is placed behind the neck the right hand presses the right side of the chest toward the *left side*

In the following exercises it will be assumed that the patient has a right dorsal curve and is in the keynote position

Exercise 38 Deep breathing Performed 20 times To a count of 5 the patient inhales to another count of 5 the patient exhales

Exercise 39 Performed 20 times Trunk is bent forward slowly and brought back to erect position to a count of 10

Exercise 40 Performed 20 times Body is bent laterally to the right as far as possible and brought back to erect position (Fig 120)

Exercise 41 Performed 10 times. Body moves through a semi-circle



Fig 121 Exercise 42

from the erect position to the right and down left arm is stretched, then back again to erect position through the same course

Exercise 42 Performed 20 times. Right lower limb is abducted forcibly and brought back to midposition (Fig 121)

Exercise 43 Performed 20 times Left lower limb is abducted forcibly and brought back to midposition.

Exercise 44 Performed 20 times. Squatting in keynote position (Fig 122)

Exercise 45 Stretching in oblique standing position Performed 20 times From keynote position patient advances right foot about 1 yard, bends knee and stretches left side of trunk, then returns to original position

Exercise 46 Performed 20 times Trunk is twisted to the right, and then to the left slowly and forcibly

Exercise 47 Performed 20 times Hands in front of chest Left arm is



Fig 122 Exercise 44

extended upward to a vertical position right arm outward on a level with shoulder

Exercise 48 Performed 20 times Hands in front of chest Left arm is extended upward to a vertical position right arm downward to the side of the body which is inclined to the right

Exercise 49 Performed 5 times Suspended from a horizontal bar by holding on with the left hand patient pulls his body up to the bar 'chinning the bar' with his left hand

Exercise 50 Performed 20 times. Patient suspends himself from a horizontal bar by holding on to bar with both hands he then moves his pelvis and legs to the right and back to neutral position.

Exercise 51 Performed 20 times In prone position with trunk projecting over the edge of the table and arms in keynote position back is flexed and extended. This is similar to Exercise 33

Exercise 52 Performed 20 times In prone position on table or floor with hands in keynote position head and chest are raised so as to look up at the ceiling

The creeping exercises suggested by Klapp (51) strengthen the back



Fig 123 Creeping exercises (51)

muscles and mobilize the spine The patient supports the trunk in a horizontal position with the hands and knees or feet on the floor (Fig 123)

Many varieties of exercises may be devised The important thing is to fit the exercise to the particular needs of the individual patient selecting those corrective exercises which will make the patient assume such positions and use such motions as will tend to straighten the curve of the spine and improve the appearance of the back A patient who has learned the corrective exercises has also acquired the habit of assuming automatically a corrected posture

Additional Methods of Spinal Mobilization

Many large and complicated machines have been invented especially by German surgeons, to supplement gymnastic exercises These machines

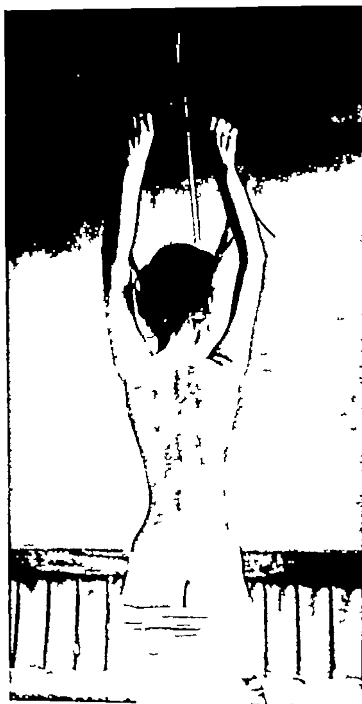


Fig 124 Suspension in a Sayre head sling to stretch the contracted tissues

are designed to increase the amount of work done and to augment the mobilization effect of exercises However the results from their use are no better than those obtained without the aid of such mechanical devices. The machines occupy a great deal of space are expensive and are so impressive as to give a false sense of therapeutic security and an unwarranted

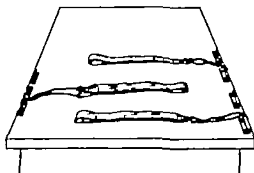


Fig 125A. Lovett s stretching table

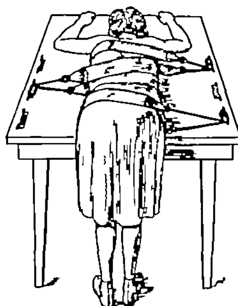


Fig 125B Patient on Lovett s stretching table

confidence in their usefulness Therefore I can see no need for them—a judgement I hold in common with other workers in this field

Since mobilization of the spine is one of the therapeutic effects of gymnastic exercises it may be well to describe briefly several other methods which can be used to stretch the spine and the contracted soft tissues.

Self suspension

This is a simple but extremely effective method The patient suspends himself by his hands from a horizontal bar or a pair of rings.

A Sayre head sling (Fig 124) may be used for the same purpose The stretching effect is increased if an assistant manually immobilizes the chest and pushes the lower limbs and pelvis to the side of the convexity

Manipulation

(1) Right dorsal curve The patient lies prone on a table, the pelvis and lower limbs are fixed by straps or by being held the surgeon pulls the left shoulder upward and toward the right side with one hand, while with the other hand he pushes the chest toward the left The patient stands upright the pelvis is held by an assistant while the surgeon pushes the left shoulder upward and pulls the right shoulder downward backward, and to the left

(2) Left lumbar curve The patient lies prone on a table the chest is fixed by straps or held by an assistant, the surgeon pulls the lower limbs and pelvis over to the left side, pressing the lumbar vertebrae to the right

Stretching Devices

Many different kinds of apparatus have been devised to stretch the spine In the Weigel Hoffa frame, for instance the patient is suspended in a head sling (e.g the Sayre sling) while pressure pads over the chest cause lateral pressure in different directions Lovett used an ordinary kitchen table on which were adjusted canvas straps worked through pulleys. The patient lies prone on the table, with the lower limbs hanging over the edge One strap encircled the shoulder girdle another the pelvis and both are pulled in the same direction A third strap, which encircled the chest is pulled in the opposite direction This apparatus is simple inexpensive and useful (Fig 125A B) The principle is the same as that of the three point pressure method described in Chapter XI.

CHAPTER XI

TREATMENT BY FORCIBLE CORRECTION

Since force cannot be applied directly to the vertebrae but must influence them through pressure exerted upon the ribs, pelvis, and shoulder girdle, forcible correction of a rigid scoliosis is a difficult problem Only a fraction of the corrective force expended reaches the vertebrae and frequently posture and the forces of respiration must be called upon as aids in straightening the spine.

The changes in the various tissues, which grow progressively worse as the scoliosis increases in severity further complicate the problem of treatment Vertebrae not only deviate from the midline but also become rotated or twisted, and forcible correction tending to correct the deviation frequently may fail to correct the rotation or vice versa. Corrective forces therefore have to be applied in different directions. Furthermore it is difficult to apply the corrective force accurately or exactly many of the involved parts such as the ribs and shoulders, move a great deal and therefore provide no absolutely fixed points against which the force may be directed

Although all the tissues of the trunk are involved in structural scoliosis, treatment is directed chiefly to the vertebrae for no real improvement can be obtained in any of the tissues without first obtaining a definite favorable change in the vertebrae and spinal column The primary objective in the treatment of scoliosis is therefore the correction of the deviation and rotation deformity of the spine

ELEMENTS IN FORCIBLE CORRECTION

Force of Gravity

An essential requirement in any treatment is to eliminate or at least to minimize the effect of the force of gravity This may be accomplished by some sort of support such as a frame canvas sling suspension apparatus, brace, or the like

Change of Posture

By changing the position of the trunk the function of the tissues and ultimately their structure may be altered Thus if in a right dorsal scoliosis the trunk is shifted to the left the right shoulder lowered and the left shoulder raised the line of weight bearing is shifted and there is less stress on the tissues on the concave side and more weight and stress on the tissues on the convex side this functional change tends to produce

a structural change which approximates the normal. The aim, therefore, is to place the patient in a posture which directly opposes the deformity.

Traction

Since the vertebrae are held together by fibroelastic cartilages, ligaments, and muscles, the spine is in effect an elastic structure which responds to both pressure and traction. Longitudinal traction is actually a very effective force. It often reduces the curvature to a remarkable degree, and even in some severe scolioses reduces the curve and improves the posture. Traction is therefore an important corrective measure.

Lateral Corrective Force

To straighten a bent rod, one holds the ends and either presses or pulls upon the area of greatest curvature. Similarly, in scoliosis in which the spine is the bent rod, the extremities (shoulder and pelvic girdles) are fixed and corrective force (pressure or traction) is applied at the apex of the curvature.

The principles or fundamental elements governing the treatment of rigid scoliosis used in various combinations for forcible correction of the deformity may be summarized as:

(*1*) Removal or reduction of the force of gravity by some form of suspension or support.

(*2*) Change of the trunk's posture so as to alter the function and ultimately the structure of the tissues, spinal and other.

(*3*) Traction for mechanical reduction of the curvature.

(*4*) Immobilization of the ends of the spine by fixing the shoulders and pelvis and application of corrective pressure or traction over the convexity of the curve: this constitutes a three-point pressure system to the back.

(*5*) Application of a rigid support.

(*6*) Gradual increase of corrective forces.

(*7*) Long-continued maintenance of corrective forces.

Supportive Apparatus

In structural scoliosis of all types the back frequently needs to be supported. Such support is valuable in mild cases, useful as a general support in moderate scolioses when no corrective treatment is being given, and essential in retaining the improvement obtained by forcible correction. After a spine-fusion operation support is advisable until the operated area becomes consolidated. In patients with a marked lateral shift of the trunk and in patients with backache supportive apparatus will be found helpful.

There is a great variety of supportive apparatus which, by and large, are

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Elements in Forcible Correction

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An essential requirement in any treatment is to eliminate or at least to minimize the effect of the force of gravity. This may be accomplished by some sort of support, such as a frame, canvas sling, suspension apparatus, brace, or the like.

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SUPPORTIVE APPARATUS

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There is a great variety of supportive apparatus which by and large are

modifications of a few general types, depending upon the ingenuity and personal preferences of the individual surgeon. A few in common use are plaster-of Paris jacket, plaster-of Paris corset celluloid corset reinforced canvas corset leather and metal corset, spinal braces

Plaster-of Paris Corset

This type of supportive apparatus (Fig 126) is frequently used When applying a plaster corset the patient should be gotten into the best possible position There is usually no difficulty in obtaining a practically corrected back in a mild curve if the patient is suspended this may be most conveniently done with a Sayre head sling If under suspension, the

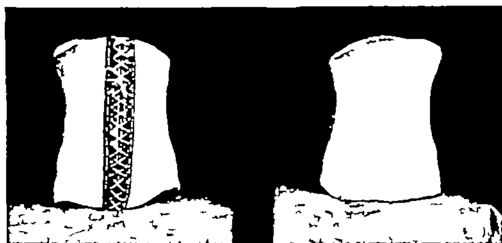


Fig 126 Plaster-of Paris corset

back is symmetric the plaster bandages are applied directly after the trunk has been mildly padded If suspension fails to improve the back sufficiently some corrective force may be exerted.

Let us assume that the patient has a right dorsolumbar curve. The procedure then is as follows After the iliac crests and the chest are adequately padded an assistant sits in front of the patient and holds the pelvis with his hands The patient then stretches his left hand upward and takes hold of the right side of the crossbar of the head sling this may correct the spinal curve If the curve is not corrected, a muslin or flannel bandage is passed around the chest and pulled gently toward the left The plaster bandages are then applied in such a manner that the corset is longer on the left or concave side than on the right side The plaster must be molded so that it fits well about the pelvis and shoulders and over the convexity Molding the plaster about the iliac crests and the great trochanters so that the corset will not slip is an important detail

When the application is complete the jacket is trimmed and cut down the middle in the front The split plaster jacket is then baked or dried in an oven or over the radiator, lined with shirting or flannel, the edges are covered with felt and eyelets are adjusted in front for lacing, converting the jacket into a corset Corsets may also be made while the patient is lying on his side or back

As the corset is made while the patient is in suspension, it is well to apply it with the patient in the same position until such time as the patient has learned to stretch his body voluntarily otherwise the corset may cause discomfort The lacing should be moderately tight so as to prevent sagging of the body within it and it is better to lace the corset from below upward

A supportive plaster-of Paris jacket is made in exactly the same manner as the corset except that when completed it is trimmed along its upper and lower margins until it is comfortable and left on the patient

Celluloid Corset

To make a lighter corset, the plaster jacket may be used as a model for making a celluloid corset The plaster jacket, prepared as for a plaster corset is filled with liquid plaster making a torso The surface is smoothed down, then 4 to 8 layers of shirting are placed upon it, each layer being painted with several coats of liquid celluloid which is allowed to harden before the next layer of shirting is applied The celluloid jacket is then cut down lined and converted into a celluloid corset (Fig 127)

I personally prefer the celluloid to other types of corsets for a number of reasons It can be made to fit accurately it is light and easily put on and removed by the patient when laced it gives adequate support to the back it is somewhat flexible but strong The cost of the celluloid corset is about the same as that of any other support

The plaster-of Paris corset supports as well as the celluloid corset, and is rapidly prepared, but it is very much heavier than the celluloid and should therefore not be used for a thin patient or in the summer in areas where the heat may be excessive

Canvas Corset

The Hoke reinforced canvas corset is preferred in some parts of the United States In my opinion the give and sag of the canvas make this type of corset less efficacious than the celluloid type yet in the hands of those expert in its manufacture and particularly in the South where extremely light apparatus is desirable this kind of supportive apparatus is invaluable.

Braces

This type of apparatus is rather expensive, and what is perhaps more important, it is not as reliable a supportive apparatus as the plaster-of Paris or celluloid corset because of its adjustable feature The two factors

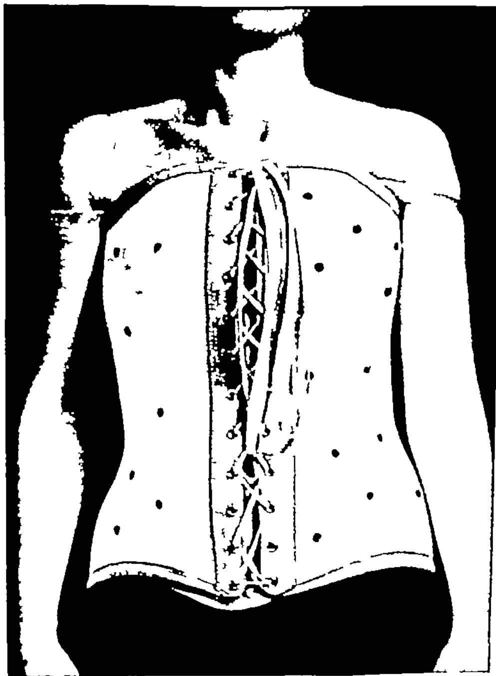


Fig 127 Celluloid corset

which militate against uniform and continuous effectiveness of spinal braces are (1) lack of proper design, and (2) maladjustment of the brace by the patient But the combination of specially trained surgeon, a skillful brace maker and a conscientious and cooperative patient can make of braces a useful supportive apparatus.

CORRECTIVE APPARATUS

In the time of Hippocrates, the corrective principles consisted of removing the deforming effect of the force of gravity and of applying traction to the spine and direct pressure over the convexity of the curve Hippocrates recommended a number of methods including the use of corrective apparatus. Retentive apparatus was first introduced in 1768 when Levacher devised a whalebone corset with a jury mast and head sling attached. This apparatus combined traction and corrective pressure together with retention of the improved position

The number of braces corsets traction tables traction beds braces applied to the trunk alone or to the trunk and head or thigh or both head and thigh chairs with flat and inclined seats, and so forth, which have since been employed is indeed legion In 1885 Fischer (29) gave illustrations of 125 different types of apparatus which had been in use since 1700 In all of them vertical lateral or oblique traction was the major corrective force some combined traction with elimination of the pull of the force of gravity, and almost all included some means for stretching the contracted tissues and altering the patient's posture to one directly opposed to that of the deformity In many of the procedures illustrated by Fischer may be seen the precursors of some of the methods in current use For example, Schreger's "Streckbett method devised in 1810 resembles the method of stretching on a convex frame which Royal Whitman and I mistakenly thought was original with us Darwin's 'Streckapparat , devised in 1801 differed little from and certainly was similar in principle to the Sayre traction halter now being commonly used. Three-point corrective traction was used by Levacher in 1768 and again by Mayor, who applied it on a couch which eliminated the pull of the force of gravity Wildberger's corrective brace which included the head goes back to 1861, the modern Milwaukee brace closely resembles its corrective features. Lorinser devised a brace in 1869 which applied corrective pressure over the trunk and extended down one thigh it is almost identical with the type of brace suggested by Steindler and which I have been using intermittently for the past 30 years In 1872 Volkmann used an oblique seat to obtain correction, it is not unlike Steindler's "compensation method"

Sayre's work gave impetus to the use of traction he combined it with

Braces

This type of apparatus is rather expensive and what is perhaps more important it is not as reliable a supportive apparatus as the plaster-of Paris or celluloid corset because of its adjustable feature The two factors

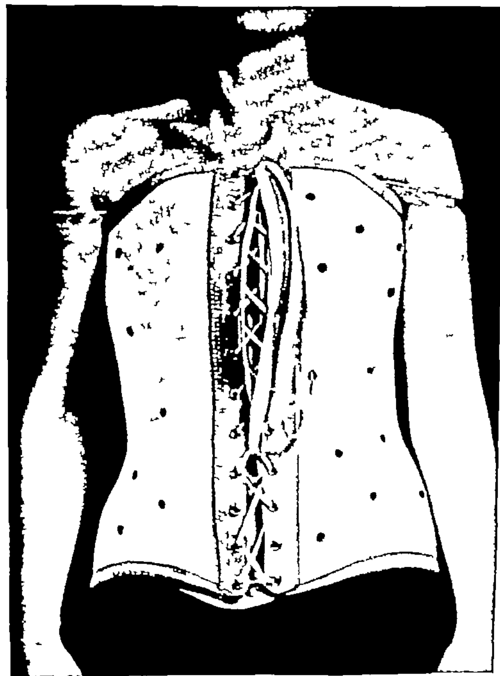


Fig 127 Celluloid corset

8 Braces (Milwaukee modified Taylor and Knight)
9 Corsets (plaster, celluloid, reinforced canvas)
10 Board with corrective pegs (for infants)
11 Plaster bed

Plaster-of Paris Jacket

There are in general two methods of applying a corrective plaster jacket The commonly employed method is to apply the jacket with the spine in extension The other method, with the spine in flexion has been largely discarded because serious disadvantages were encountered when this method was used In applying a plaster-of Paris corrective jacket the principles comprise the following conditions (*1*) spine in extension (*2*) pelvis and shoulders immobilized (*3*) hollow regions padded with felt or similar material during application of plaster jacket so that when the jacket is complete and the padding is removed there is room for expansion of these parts (*4*) corrective pressure or traction applied over the convex portions of the curve, pressure may be in a lateral direction (toward the hollow side) which tends to correct the deviation of the spine or it may be in an anteroposterior direction, which tends to correct the rotation of the vertebrae; or pressure may be in two directions simultaneously tending to correct both deviations and rotation

Jackets holding the spine in extension may be applied while the patient is in one of several different positions (*1*) Patient standing suspended by the head resting lightly on toes and heels the arms may be raised above the head or abducted to about 90 degrees (*2*) Patient sitting on a horizontal or inclined seat with the head pulled up in a Sayre or other head sling (*3*) Patient lying prone in a special apparatus with the thighs flexed or extended (*4*) Patient lying on the side of the convexity, with trunk suspended in lateral bending position by a canvas or flannel band

After the jacket is completed windows are cut out of the plaster over the hollow regions In a right dorsal left lumbar curve a window is cut out over the left side of the chest in the back and the right side in the front If the right side of the lumbar region is hollow a window would also be cut out here

Depending upon the type and location of deformity, plaster-of Paris jackets may include the shoulders neck head and one or both upper or lower limbs High dorsal and cervicodorsal curves cannot be treated effectively by any method unless the head is included and even then not very satisfactorily

Corrective force is exerted either through pressure pads as in the specially designed apparatus of Schulthess, Hoffa Wullstein and others, or by traction bands

support in a plaster-of Paris jacket Wullstein was among the first in modern times to advocate the use of great force to correct the curvature, he employed strong traction and lateral pressure for correction and a plaster jacket for retention. Wullstein and many others applied the treatment with the spine in extension. In 1912 Abbott (1a) announced that the spine could be derotated in flexion and scoliosis readily cured he devised an apparatus in which the patient was suspended in a fixed recumbent position and correction obtained by traction over the deformity In Italy Galeazzi (31) devised a method of derotation by suspending the patient in the prone position using corrective traction and applying a retentive apparatus Lovett and Brewster (63) used distraction and leverage at the apex of the deformity by means of a turnbuckle jacket Risser (74) devised the hinged turnbuckle jacket

Thus through the ages to the present time the principles of treatment in the numberless methods of correction have been about the same namely, removal of the influence of the force of gravity traction in the longitudinal horizontal or oblique directions corrective pressure and the use of a support Gymnastic exercises and spinal apparatus came in as secondary aids The special contribution of this century so far has been the use of surgery, and particularly spine fusion as a means of retaining improvement When a new procedure is acclaimed as a "new" method search is apt to disclose that something like it has already been used In principle at least if not in every technical detail, all of the nonoperative therapeutic methods in use today have at some time or another been utilized in the past

Methods of Forcible Correction

While the principles of treatment are virtually the same different combinations of technical details constitute different methods Since the results of the various methods are approximately the same only the most popular procedures need be described The following is a list of the methods of forcible correction commonly employed at present.

1 Plaster-of Paris jacket
   a. Simple with three-point pressure
   b Jacket including part or all of head
   c Jacket with hip and/or shoulder spica
2. Risser hinged turnbuckle jacket
3 Galeazzi jacket
4. Lovett Brewster turnbuckle distraction jacket
5 Lateral flexion jacket
6 Traction on convex frame
7 Fishnet traction (Le Mesurier)

of traction and pressure which the patient tolerates *comfortably* It is unwise to use anesthesia when applying a corrective jacket, for one is then deprived of the means for estimating whether the force applied is within the limit of the patient's endurance.

Particular caution is essential in using corrective force for a paralytic scoliosis Due to paralysis or weakness of some of the muscles of the back, chest or abdomen, the body yields readily to corrective pressure and severe pressure symptoms, such as abdominal distress, chest pain and dyspnea may appear When the jacket is first applied, no attempt should be made to accomplish a marked change To avoid the danger of diminished chest expansion exceptionally deep breathing should be encouraged

Jacket Applied in Vertical Suspension I have obtained good results with the extension method and have in recent years used this method almost exclusively In a typical case of long right dorsal slight left lumbar curve with flattening of the left side of the chest posteriorly and of the right side anteriorly (Fig 128A B) the following procedure would be employed

The patient, having put on a seamless shirt is suspended by the head in a Sayre sling so that the feet rest lightly on the floor In the average case this at once improves the appearance of the back and reduces the curve of the spine (Fig 128C) The patient raises the left arm and inclines it to the right (Fig 128D) this stretches the left side and helps to increase the correction. A felt or sheet-cotton pad is placed *under* the shirt on the left side of the back extending from the spine to the left anterior axillary line and from just below the shoulder to the beginning of the lumbar curve at about the second lumbar vertebra. The pad is thickest in the middle and is much larger than necessary to fill out the hollow so as to allow room for increased correction after the jacket has completely hardened. Another pad is placed under the shirting over the right side of the chest in front, extending from the posterior axillary line to close to the sternum The convexities of the chest particularly the one in the back are well protected with fairly thick pads which are placed *over* the shirting and adjusted evenly these pads are the ones to be left under the jacket The iliac crests and the sacrum are also protected with pads. Beginning at the right shoulder a long pad is placed in front across the chest over the left axilla high up and over the upper part of the back to the right side A pad is then placed over the right shoulder (originally the high shoulder) which is now depressed and pulled back by an assistant If the patient is a girl with well-developed breasts a protective pad should be placed over them To avoid undue pressure on the abdomen, a removable pad is placed over the abdomen *under* the shirting

The pelvis is fixed by a band secured on the right side and the shoulders

If the jacket has been well fitted, the proximity and rigidity of the plaster over the convex portions of the curve restrict motion here so that the forces of inspiration expend themselves, at least in part in forcing out the hollow parts through the windows that have been cut in the jacket. No jacket can or should be made so tight that any part of the trunk is absolutely fixed or immobilized. But if a jacket has been well applied, it can be readily determined by inserting one hand through a window in the jacket and placing it near the convex side and the other hand over the concave side that the chest expands considerably more on the hollow side than on the convex one

Metal pads, pneumatic bags, cotton felt pads and other materials may be used to continue or increase the corrective pressure of the completed jacket Felt pads are probably the easiest to handle they can be made to lie evenly and are readily adjusted in shape size, thickness and location If felt pads are used, they should be from ½ to 1 inch thick additional pads are inserted every few days or every week as indications and tolerance of the patient dictate Pressure pads tend to reduce the convexity and favor expansion of the concave or hollow side by limiting the expansion of the convex side In any given jacket 2 to 6 felt pads are usually inserted over the convexity posteriorly and a few over the convexity anteriorly It is generally assumed that as the ribs change their position under the pressure of the jacket and the pads, they carry with them the corresponding vertebrae and thus produce a reduction of the deformity of the spine

Jackets should be changed every 2 to 8 weeks for in applying a new jacket one may be able to correct the spine a little more or hold the patient in a better position than in the preceding jacket The intervals between jackets are determined by the time it takes for the chest on the hollow side to fill out and reach the plaster once that point is reached the chest lacks room for further expansion Not all surgeons use pressure pads some prefer to apply jackets frequently (every 2 to 3 weeks), attempting to get increased correction with every new jacket

Wullstein used a special apparatus for applying a jacket The patient sits on a movable seat to allow for tilting of the pelvis, is suspended by a head sling and the head neck and shoulders are included in the jacket. Metal pads supply the medium of applying pressure This apparatus makes possible the use of a great amount of force both in traction on the head and by pressure pads but I must emphasize that the use of great force is not without danger Pain dyspnea tachycardia and prostration may occur and severe pressure may result in pressure sores and extensive ulcerations

The only safe guide in using corrective force is to employ only the amount

of traction and pressure which the patient tolerates *comfortably* It is unwise to use anesthesia when applying a corrective jacket for one is then deprived of the means for estimating whether the force applied is within the limit of the patient's endurance

Particular caution is essential in using corrective force for a paralytic scoliosis Due to paralysis or weakness of some of the muscles of the back, chest or abdomen the body yields readily to corrective pressure and severe pressure symptoms such as abdominal distress chest pain and dyspnea may appear When the jacket is first applied no attempt should be made to accomplish a marked change To avoid the danger of diminished chest expansion, exceptionally deep breathing should be encouraged

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The pelvis is fixed by a band secured on the right side and the shoulders

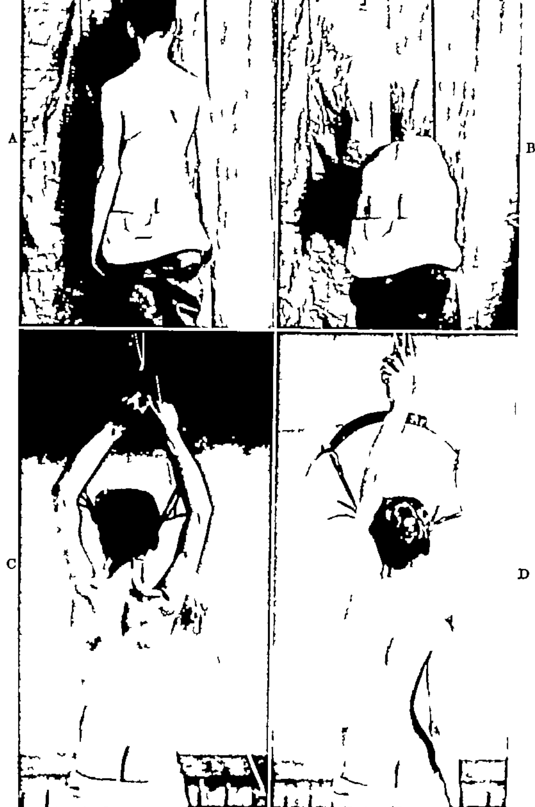


FIG 128 Correction of a right dorsal scoliosis A Patient in upright position B Patient in forward bent position C Patient suspended in a Sayre head sling D Curve reduced attitude of deformity reversed shirting has been omitted to show correction

are fixed by a band passing over the left axilla and pulled to the right A muslin bandage, 4 to 6 inches wide and about 3 yards long, is then passed about the chest at the site of maximum deformity, with the ends projecting on the left side, an extra piece of padding over the deformity under this traction bandage is advisable An assistant standing to the left

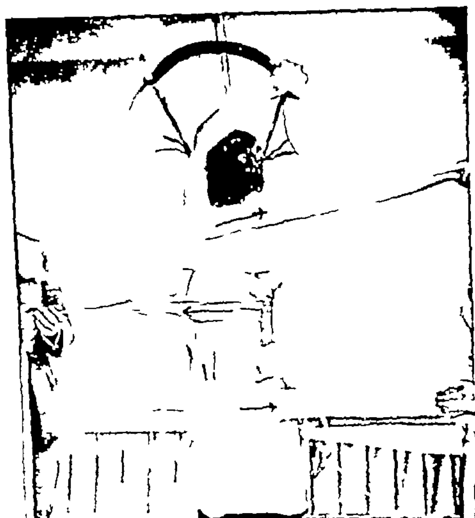


Fig 128 F Three point pressure procedure traction bands over shoulder and pelvis corrective band over apex of curve (arrows indicate direction of pull)

of the patient pulls this traction band to the limit of the patient's tolerance, since the shoulders and pelvis are fixed, the deformity in all but the severest cases will be materially reduced by this pull on the band (Fig 128 F)

The right shoulder is included in the jacket and care must be taken during the entire application of the plaster that the right shoulder is pushed downward and held back as much as possible To reduce the time occupied in making the jacket prepared plaster reverses are utilized to reinforce the parts of the jacket that should be particularly strong. Appli

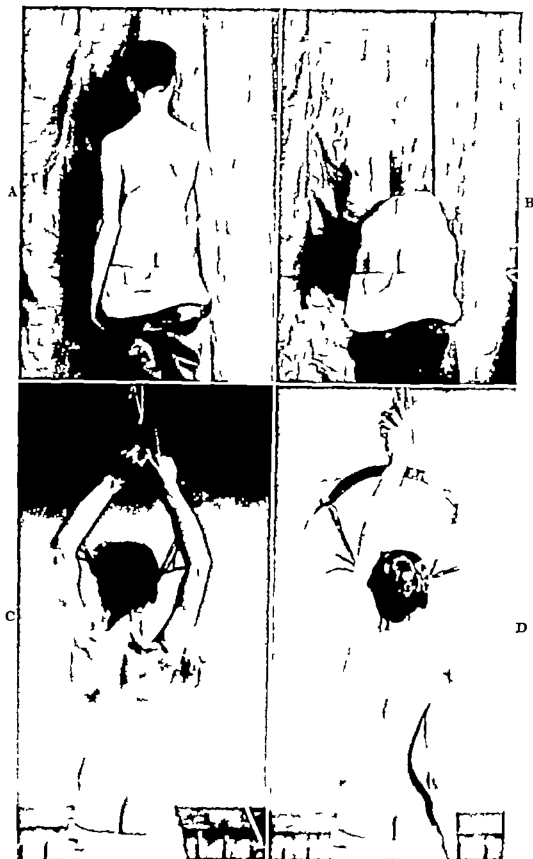


FIG 128 Correction of a right dorsal scoliosis A Patient in upright position B Patient in forward-bent position C Patient suspended in a Sayre head sling D Curve reduced attitude of deformity reversed shirting has been omitted to show correction.

correction (Fig 120) If the curve is in the cervicodorsal segment, the plaster should include both shoulders and extend to the occipital protuber

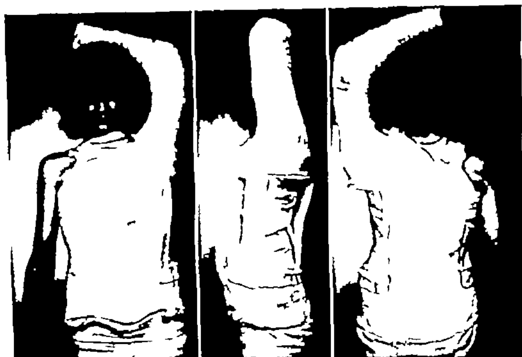


Fig 129 Plaster shoulder spica jacket for increased correction



Fig 130 Calot plaster jacket for cervicodorsal curve

ance in the back, under the ears laterally and to the chin in front, that is, a Calot type of jacket (Fig 130) The jackets are changed every 4 to 8 weeks changes at more frequent intervals are inadvisable for sufficient

cation of the plaster bandages is now begun, starting at the pelvis fairly low down and rolling the plaster snugly so that the jacket will get a good grip on the pelvis The plaster is applied about the right shoulder and the jacket is completed in the ordinary way Plaster reverses are applied over the right shoulder, under the left shoulder over the convexities in back and front and across the back at about the dorsolumbar junction When the plaster is about to set it is pressed forward over the convexity in the back *so that it may be snug and fit well at this point Once the plaster has* hardened the jacket is trimmed in the usual way The plaster is left on over



FIG 128 F Posterior view of completed jacket G Anterior view of completed jacket

the right shoulder and is cut as high as is compatible with comfort under the left shoulder (Fig 128F–G) A large window is cut out over the left side in the back another one may be cut out on the right side in front, and the removable pads are taken out Such a jacket is asymmetric being larger and longer on the left side than on the right and allows for expansion of the compressed parts of the chest

The jacket is somewhat modified when the lumbar curve in a right dorsal left lumbar scoliosis is well marked An additional traction band is then used to pull the lumbar spine to the right a removable pad is inserted over the right side of the lumbar region and a window is cut out here in the jacket When the curve is a high dorsal one it is often advisable to include in the jacket the arm on the concave side of the curve for more effective

correction (Fig 129) If the curve is in the cervicodorsal segment, the plaster should include both shoulders and extend to the occipital protuber

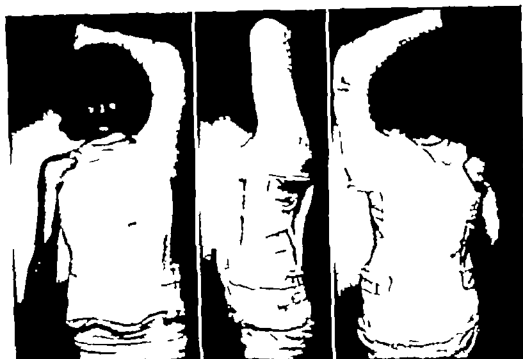


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ance in the back, under the ears laterally and to the chin in front that is, a Calot type of jacket (Fig 130) The jackets are changed every 4 to 8 weeks changes at more frequent intervals are inadvisable for sufficient

time must be allowed for the tissues to adjust themselves to the new position

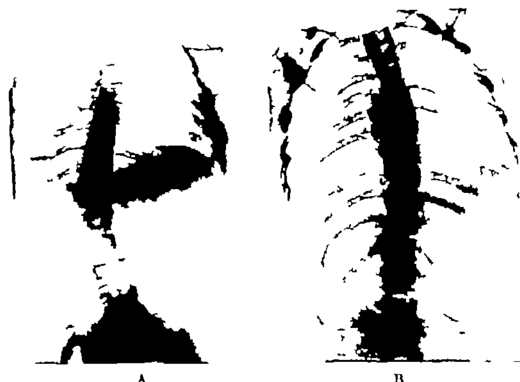
Considerable correction may be obtained by inserting pressure pads over the convexity of the chest in the back Discomfort increases with each additional pad, and only a few pads can be tolerated in any one jacket The patients are advised to practice forced breathing in the "keynote position from 5 to 10 minutes every 2 to 3 hours. During these breathing exercises the patient forces himself over to the left side by raising the left arm as far as possible inclines his head to the right, and places his left hand behind the neck

Since the spine tends readily to relapse to the old or original condition of deformity as soon as the plaster jacket is removed, I have adopted a special procedure during changes of jackets The old jacket is cut in front and over the shoulder the patient is then suspended until the feet rest lightly on the floor and the jacket is removed. The skin is washed and the patient is prepared for the new jacket When this procedure is followed the tissues cannot relapse to their original condition, and any correction gained in the preceding jacket is retained and is augmented in the new jacket My experience with this procedure leads me to recommend its general adoption

While the weight of an ordinary jacket is rarely a disturbing element, and patients rarely complain of it, the pressure a jacket exerts and the unevenness of its inner surface cause a certain amount of discomfort. Undue pressure results either from too tight an application of the bandages or from an attempt to use too great a corrective force The former is easily avoided plaster bandages should never be applied so tightly that they cause constriction they should be rolled on and never pulled around Furthermore if the bandages are rolled around smoothly and rubbed so that they form even layers unevenness of the inner surface can be avoided This detail is important an uneven inner surface allows formation of more or less sharp ridges which press on the skin and produce pain and ulcerations. Pressure is a necessary part of the treatment but it should be present only over the convexities of the curve and must never pass the limits of the patient s comfortable tolerance Dyspnea palpitation, pain insomnia loss of appetite prostration and ulceration of the skin may occur when the pressure is too great Since ulcerations can occur without causing much discomfort they should be carefully watched for and avoided their occurrence usually interrupts treatment for a number of weeks and permits a relapse of the deformity The maceration of the skin when ulcerations occur under plaster produces a peculiar and easily recognized odor With one s nose as a guide therefore excoriations of the skin can be avoided in most cases by careful supervision

A jacket applied with the spine in extension as a rule inconveniences a patient only for the first few days He soon accommodates himself to the new position and is able to continue with most of his daily routine Among my patients with "straight jackets there are a good number who go to school regularly, take music lessons, and spend much time out of doors When a new jacket has to be applied, they hardly ever lose more than a day from school and the treatment is at no time excessively uncomfortable.

Figures 131 132, and 133 are examples of the degree of correction ob-



A B

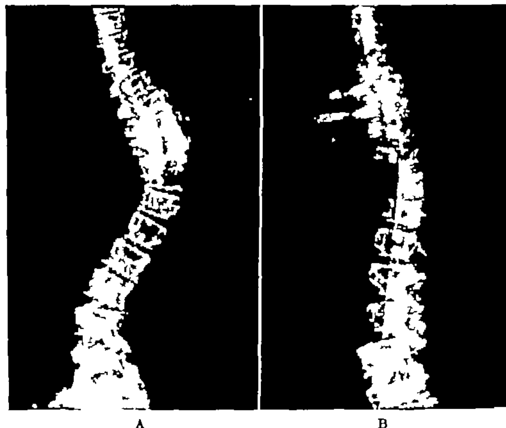
Fig 131 Mild left dorsolumbar structural scoliosis A Before correction B After correction

tainable by applying three-point pressure in a straight plaster-of Paris jacket.

Traction on a Convex Frame

While the ' straight jacket is an excellent means of obtaining correction in scoliosis, correction or rather reduction of a spinal curvature may be attained equally well more rapidly, and with less discomfort to the patient by means of traction on a convex frame The treatment may be carried out in the patient s home but is more effective in the hospital, and in my cases is used only in the hospital The patient remains on the convex frame (Fig 134A) throughout the entire period of treatment A Sayre

halter at the head of the bed applies longitudinal traction to the head and a pelvic girdle serves the same purpose for the lower part of the spine. When there is a marked lateral deviation of the spine, lateral traction (Fig 134B–D) is applied through a canvas strap encircling the chest at the apex of the curve Traction is increased gradually by means of weights attached to the Sayre halter and to the pelvic girdle· for this purpose the latter has a canvas strap on each side which passes down to the foot



A B

Fig 132 Moderate right dorsal scoliosis A Before correction B After correction

of the bed and continues by a cord passing over a pulley When a lateral traction band is used weights are also attached to this band on the side of the concavity

Treatment is begun with 5 pounds of traction on the head 5 pounds on each side of the pelvis and 5 pounds over the chest (if lateral traction is used) The weights pulling on the pelvic girdle are increased much more rapidly than the others a 13 year-old child in good health will tolerate with ease 75 to 100 pounds of total traction Maximum improvement as shown roentgenographically can be obtained within 4 to 8 weeks

During the period of treatment the patient is provided with a set of blow

bottles, these should be used several times a day to ventilate the lungs thoroughly and to increase the amplitude of respiration Twice a day the traction straps are released for 30 minutes each time and gradually increased exercises are given for the trunk and extremities Gentle massag ing of the muscles once a day is a further aid in maintaining good muscular tone

The method of traction in recumbency makes use of a number of factors

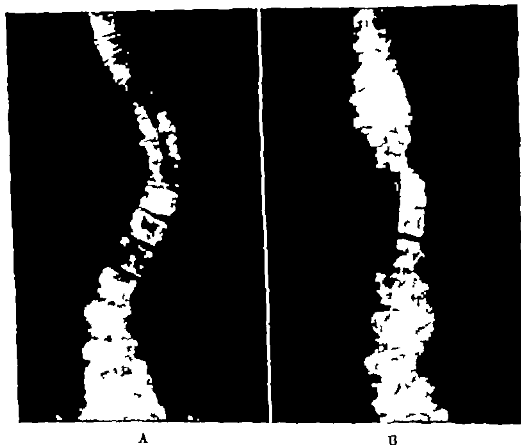


Fig 133 Moderate right dorsal scoliosis A Before correction B After correction

which are important in reducing the deformity The advantages of recumbency in the hyperextended position are (*1*) the scoliotic deformity is always less marked in extension of the spine than in flexion (*2*) the force of gravity which in the erect position tends to increase the spinal curvature is eliminated as a deforming factor (*3*) lying on the convex ribs tends to flatten them, (*4*) the expansion of the chest is increased (*5*) the anterior flattening of the chest is reduced as a result of the freer excursion of the ribs.

The traction because it is unopposed by the force of gravity, reduces the curvature more rapidly than traction in vertical suspension Forced

respiration increases the vital capacity and gymnastic exercises help to maintain good muscular tone and a sense of well being

The disadvantages of this method of treatment are the interruption in

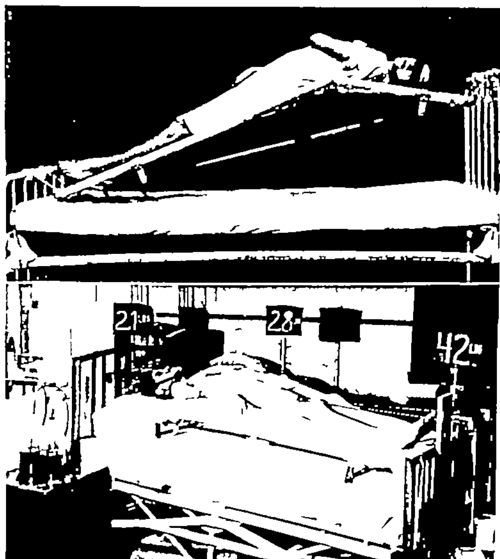


Fig 131 Traction on the convex frame A (upper) Patient on convex frame B (lower) Longitudinal and lateral traction applied. Note C and D on opposite page

the patient s educational and social activities which it entails and the cost of *hospitalization However the rapid attainment of maximum correction* more than compensates for these disadvantages.

After maximum improvement has been obtained the patient is provided with a supportive plaster jacket Since after 4 to 8 weeks in bed the patient is not likely to be able to stand up without undue discomfort for



Fig 134 C

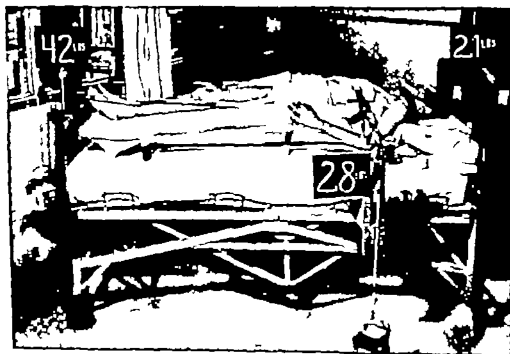


Fig 134 D

respiration increases the vital capacity, and gymnastic exercises help to maintain good muscular tone and a sense of well being

The disadvantages of this method of treatment are the interruption in

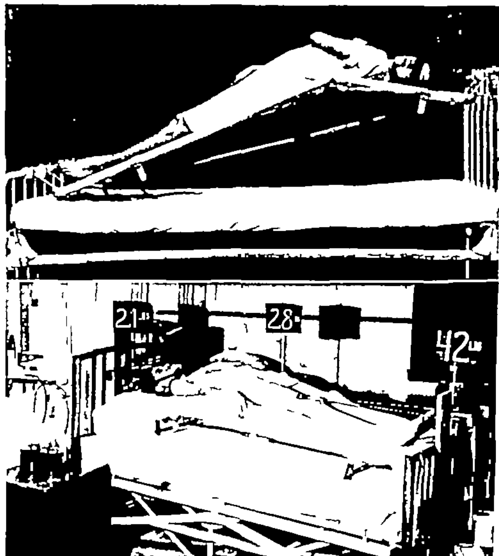


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(Fig 138) Good results had been obtained in a limited number of cases Their method did not become very popular, but it is a good one and deserves wider knowledge A full description of it will be found in Lovett's *Lateral Curvature of the Spine* (62)

This method, too, applies several principles of forcible correction—reduction of the influence of the force of gravity, traction through distraction of the ends of the dominant curve support of the trunk in the



FIG 136 Moderate right dorsal scoliosis A Before correction B After correction on a convex frame

improved posture It is noteworthy that although the turnbuckle jacket makes use only of traction both the rotation and the deviation elements of the curvature are effectively and simultaneously influenced

Lovett's conclusions on the results of treatment with the turnbuckle jacket are as follows

1 No type of curve which is of long duration with marked rotation and in which ankylosis has occurred can be affected in the least by the method of treatment described

2 Single curves either right or left the apexes of which are below the eighth dorsal vertebra are the ones most favorable to correction by this method

3 Double curves either right or left with the apex of the upper curve not higher

the 20 minutes it takes to apply a plaster jacket, it is applied on a Goldthwaite frame or on one of the newly designed frames which permit recumbency and traction The patient can then get out of bed and walk about This first jacket while effective as a support is unattractive, being unusually flat in front or back depending on the kind of apparatus used for its application After about a week, therefore the patient is suspended in the standing position and a well fitting, new plaster-of Paris jacket is applied Several days thereafter the patient is discharged from the hospital



Fig 135 Moderate right dorsolumbar scoliosis A Before correction B After correction on a convex frame

This jacket is kept on for several months (6 to 12) after which the patient is ready for a corset and corrective gymnastic exercises.

While traction on a convex frame may be used as a conservative method of correction it is equally useful and the preferable procedure in preparation for a spine fusion. It is particularly indicated in the treatment of paralytic scoliosis

Figures 135 136 and 137 illustrate the degree of correction that may be obtained by the use of traction on a convex frame

Distraction Turnbuckle Jacket

In 1924 Lovett and Brewster (63) described a new method of treating scoliosis with the spine in extension by a turnbuckle hinged plaster jacket

than the eighth dorsal vertebra can be helped but are not nearly so amenable to treatment as single curves

4 Triple curves do not lend themselves to treatment at all



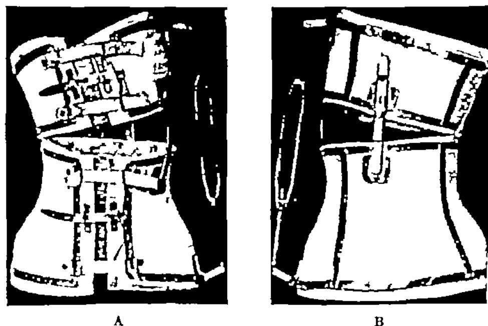
FIG 139 Risser hinged turnbuckle jacket (74)

Risser Method

This method (74) makes use of a hinged turnbuckle plaster-of Paris jacket Forcible correction is obtained through preliminary head traction and immobilization in a plaster-of Paris jacket extending to the occiput and down one thigh and subsequent distraction of the transversely bisected jacket by means of hinges secured near the apex of the deformity front and back and a turnbuckle on the concave side of the curve (Fig 139)

A B

Fig 137 Severe right dorsal scoliosis A Before correction B After correction on a convex frame



A B

Fig 138 Distraction turnbuckle jacket (62) A Front view B Back view

for 12 weeks, after which the jacket is removed and anteroposterior and lateral oblique roentgenograms are taken A semibent jacket is applied immediately In this ambulatory jacket the patient is relaxed yet bent against the corrected curve With one or two changes this jacket is worn for the next 6 to 9 months, or until fusion is adequate as shown by the roentgenograms All support is then removed, and the patient begins postural exercises.

For the antigravity jacket recommended by Risser in cases in which spine fusion is not indicated or refused, the patient lies supine on the sagging canvas belt This allows a flattening of the lumbar spine and hyper extension of the thoracic spine over the crossbar The body jacket creates a retraction of the abdomen and a thoracic elevation by opposing the gravity curves The lateral bend is less than the one in the turnbuckle jacket, and because the correction of the anteroposterior curves renders this position physiologic the patient suffers no ill effects from being in the jacket for long periods.

The type of jacket advocated by Risser differs little *in principle* from the type already described as a straight jacket with longitudinal and lateral traction or the turnbuckle jacket devised by Lovett and Brewster

Turnbuckle Brace

Satisfactory use of such a brace in a limited number of cases was reported by Barr and Buschenfeldt (9) in 1936 Forcible correction was applied to the spine in extension by means of three point pressure

The authors state "This brace is most effective in the correction of single flexible curves but it is also applicable in certain cases of structural double curves which are not fixed Operative procedure and exercises are not supplanted but supplemented by this brace"

Preoperative Correction in a Net Hammock

Le Mesurier (60) seeking a simpler method than the Risser turnbuckle plaster jacket to prepare a scoliotic patient for a spine fusion, has devised the following method. For a gradually increasing time each day the patient is placed in a net hammock and the ends of the hammock are raised toward the ceiling with the body rather sharply bent so as to correct the primary curve (Fig 140) When the patient has become accustomed to this bent position (from 7 to 10 days) a plaster jacket is applied with the patient hanging in this position in the hammock. The jacket extends from the head to the feet (Fig 141) After a window has been cut in the back of the jacket the patient is ready for a spine fusion operation While his method is no better than the Risser jacket Le Mesurier is convinced that it is

The jacket is applied with the patient in the supine position, thus eliminating the force of gravity When maximum correction has been obtained a window is cut out of the plaster over the spine if a spine-fusion operation is to be performed or if conservative treatment is to be continued, the hinged jacket is replaced by a simple, straight or so-called "antigravity" plaster jacket

The hinged, turnbuckle jacket is applied with the patient lying supine on a horizontal canvas attached to a rectangular frame The traction on the head and pelvis is moderate Pads are inserted over all bony prominences, two or three layers of felt are placed under the site of the anterior hinge and are later removed allowing space for correction of the chest deformity For better distribution of pressure and the greater comfort of the patient a headpiece and hip spica are added on the convex side of the curve with basswood struts to reinforce the spica portion.

The jacket is dried for 3 to 5 days and then sectioned on the concave side to the point of motion of the front and back hinges A turnbuckle is attached to lugs made of 2 pieces of plumber's tape riveted together to form a right angle and inserted over the cut edges on the concave side of the jacket On the convex side, the jacket is fenestrated between the hinges to allow for lateral bending

Each morning the turnbuckle is turned, but if the patient is uncomfortable the increase is reduced by 50 per cent in the afternoon All pressure points usually found under the hinges and at the window edges must be corrected Roentgenograms are taken periodically to check on the amount of correction. A straight line drawn on the jacket through one arm of the anterior hinge and dated at the time a roentgenogram is taken serves as a guide to further bending When the hinges have passed dead center, as shown by the roentgenograms, no further correction by traction can be obtained the only further correction obtainable is bending correction at the ends of the correcting curve.

Sufficient correction having been obtained the jacket is prepared for a spine fusion operation by reinforcement on the sides with plaster-covered basswood struts, removal of the turnbuckle and lugs, and opening a large window in the back over the proposed fusion area (Fig 139) A lead marker is placed over any prominent spinous process of the proposed fusion area and a roentgenogram is taken. The fusion area comprises a certain number of vertebrae above and below the marked spinous process 5 or 6 vertebrae is the average number of vertebrae fused at one time. As fusion is more difficult when performed through a window in the jacket, it may be done in two or three stages at 3-week intervals

The jacket is reinforced postoperatively and the patient remains in bed

direction as in the first jacket, a loop of plaster is added to the jacket over the shoulder Depending on the degree of correction and the muscle strength, the straight jacket is worn for as long as 1½ years

Milwaukee Brace

This apparatus (Fig 142) which effects correction with the spine in extension, is a well fitting brace with a head and chin cup and a pressure pad for the convexity The two corrective principles utilized are traction on the spine through the head pull and pressure force over the convex ribs



FIG 141 Posterior view of completed plaster jacket (60)

Blount and Schmidt (14) its originators state that it should stay on uninterruptedly during treatment and should also be used to hold the spine in the corrected position during and after a spinal fusion The principle of this type of forcible correction has been used before, Wullstein used the same method with plaster-of Paris jackets but without surgery, and I have employed a similar brace with the body in flexion There is no doubt that in the hands of surgeons familiar with every detail of the apparatus the Milwaukee brace is giving favorable results. The description which follows has been taken from a personal communication of Blount and Schmidt

'The orthopaedic surgeon suspends the patient until there is a comfortable degree of correction The torso is steadied by a frame while plaster is applied from below

as good In his opinion the stiff primary curves can be corrected to a certain degree by a moderate bending force and no further force within the bounds of the patient's tolerance will prove effective



FIG 140 Patient suspended in net hammock ready for application of plaster jacket (60)

The original bent jacket is retained for about 3½ months after the last fusion operation after which a shorter straighter jacket is applied in which the patient can walk about To keep the neck bent slightly in the same

the contours of the leather It is attached to chin and occiput supports by adjustable bars The latter must be carefully constructed so as to combine extensibility with lightness and strength The best plan has been to use two extensible bars on each side These are activated on each side by a strong turnbuckle The bars and turnbuckles are usually replaced by longer ones during the correction On the cephalad end of these uprights is a circular band carrying two adjustable bars in back and one in the front The anterior mid line bar must be made of aluminum The chin support is fastened permanently to the anterior bar The occiput and chin supports are fastened together on either side by two screws with several adjustments This makes it possible to increase or diminish the front to back diameter of the chin occiput support A movable tilting head piece has been tried and found undesirable except perhaps in polio patients who are to wear the brace a long time without operation A movable head piece is less effective in obtaining correction The patients have stated that the rigid one is more comfortable postoperatively

At the apex of the convexity an aluminum reinforced sponge rubber pad is attached to the extension from the cross bar It must be made easily removable and adjustable as to location and pressure In most cases it must be displaced cephalad and sometimes forward or backward during the correction The exact mechanism will depend upon the ingenuity of the brace maker The Warm Springs method of advancing the pad by increasing length of pins is the simplest

Do not fail to notch the occiput pad so as to avoid pressure on the occipital protuberance The pelvic girdle must be amply long and snugly fitted in the waist The chin piece is best left as a padded platform with maximum support along the margins of the mandible There is no need for an anterior rim on the chin piece The horizontal bars should be well below the axillae There is no crutch action

"When the brace is completed in the rough it should be fitted to the patient standing and even *more important* lying down After it is padded and finished off it should be applied by the brace maker and inspected by the surgeon It should fit loosely with only slight corrective force No additional correction of the curve should be obtained at this time The patient should be able to raise his chin and occiput simultaneously from the head support or rest the head on its support and shift the chest away from the lateral pressure pad This situation must prevail at all times during and following correction Never use sufficient force to cause pressure The appearance of pressure areas is evidence that the method is wrongly used With the patient in the prone position the pelvic girdle should be loosened and the skin of the entire torso given nursing care at least twice a day It is important to inspect the skin over pressure points

"There must be no pain at the tempero-mandibular joints and no prolonged pressure on the chin The chin must be capable of protrusion at any time The patient must be able to eat freely while lying down Vigorous distraction with intermittent pressure on the jaw will obviously increase the pressure on the teeth In younger children protrusion of both upper and lower teeth has been noticed This has receded rapidly upon removal of the brace after completion of the treatment in every case Competent authority has stated that permanent deformity is not likely to occur Pain at the tempero-mandibular joint or pain in the teeth is an indication for release of distraction pressure

A marked over bite is a frequent finding in idiopathic scoliosis as noted by Chandler Care should be taken to examine the jaw prior to the onset of treatment Jaw deformities should not erroneously be ascribed to the brace No change of bite has been observed

the trochanters to the head The pelvic portion is applied first and molded well over the crests of the ilia as an assistant continues up the chest The plaster should extend one inch or two on either arm It is appropriately reinforced with plaster slabs Before it begins to set over the rib cage the lower half is cut in back to permit abdominal breathing A rope is incorporated under the plaster in back to facilitate this Good posture must be maintained until the plaster is entirely set It is essential to avoid rotating or tilting the head in its relation to the pelvis Mold the plaster about the chin and occiput

As soon as the plaster has set the rest of the cast is cut up the back. A cut perpendicular to the first must be made along the back of each shoulder The shell is then removed and restored with plaster slabs and circular turns The brace maker pours a plaster positive which the orthopaedic surgeon or the brace maker then

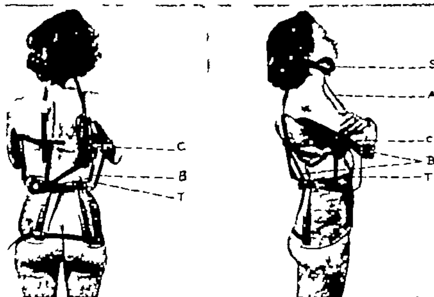


FIG 142 Milwaukee brace *A* Anterior midline bar *B* Extension bars *C* Circular band *S* chin support *T* turnbuckle (Courtesy of Dr W P Blount)

shaves just above the iliac crests to insure a snug fit through the waist Along the costal margin the model is built out abruptly above the constricted waist on the side opposite the convexity *for one or two inches* This space is necessary to accommodate the chest after correction Over both anterior superior iliac spines the model is padded one-eighth inch with felt A heavy sole leather foundation is molded wet over the plaster positive and the ends tacked in back The patient will be more comfortable in bed if the leather is left low in the groins and not cut high enough at first to facilitate sitting It should curve upward in front to support the abdomen but must be cut lower on the sides to avoid pressure on the costal margin The metal parts are fashioned by the brace maker and loosely fitted to the model leaving about one inch clearance except on the side opposite the lateral pressure pad Here one must leave additional room If in doubt it is safer to have the brace too large than too small A large brace is bulky under the clothing One that is too small will bind and interfere with the corrective effect of the lateral pressure pad

The pelvic girdle is reinforced by metal bands which should be curved to fit

If overcorrection has been obtained some of the support may be withdrawn and the error corrected

"The full correction should be obtained after two weeks but the fused spine can be bent for a much longer period There is danger of loss of correction or pseudarthrosis if too early ambulation is permitted The patient should be kept recumbent for four to six months after the last operation A small pillow should be kept between the posterior bars and the skin There is no objection to the patient rolling over by himself An amazing degree of freedom is possible without placing a harmful strain on the graft The general condition of the patient remains very good as compared to that of a cast case The physiotherapist gives general exercises with special attention to proper breathing and abdominal retraction

"When the patient first gets up he should not attempt to sit He may stand and walk Later when he returns to school the pelvic band may be cut away in each groin to permit sitting The brace should be worn a total of eight months or more following the last operation It is tolerated better than a bent cast No period of rehabilitation is necessary at the end of the treatment The brace should first be discontinued at night then during the day The patient should have a corset for abdominal support Additional rest will be necessary for a time The patient must be followed closely for the first month so as to watch for postural defects and excessive fatigue"

Plaster-of Paris Bed

This type of apparatus (Fig 143) is useful in the treatment of infants, or of older children with mild curvatures In contrast to the methods just described the plaster bed provides the gentlest corrective force Its primary value is that it eliminates the force of gravity as a deforming factor and that it makes possible maintenance of an improved or corrected posture for the greater part of each day In Germany, where the plaster bed probably originated it has been rather extensively used for many years In the United States however, the tendency is to resort to more effective therapeutic means Nevertheless although of limited usefulness, it is a valuable aid in treatment

The plaster bed method is particularly useful for patients with paralytic scoliosis who have marked curves which are obviously growing worse and with other deformities and paralyses besides that of the spine who are thin weak and generally unfit subjects for forcible correction in jackets. A prolonged course of treatment in a plaster bed (6 to 12 months) may lead to improvement or at least prevent the deformity from becoming more severe. The patient rapidly becomes used to the bed and feels comfortable in it When the bed is being made the hollow side of the chest is padded in order to allow room for this side of the back to expand A daily alcohol rub will keep the skin clean and massage will maintain muscle tone

While the patient is undergoing this treatment in the recumbent position, special gymnastic exercises will help to improve his general condition

The Milwaukee brace is being used for both the conservative and operative treatment of scoliosis. The authors' directions for using the brace with spine-fusion operations are as follows

"The brace is worn for a preliminary period of two weeks or more before operation Any necessary adjustments should be made during this time rather than later when the patient is confined to the hospital If any pressure areas appear or if the patient is uncomfortable he may remove the brace by unbuckling three straps and removing six screws This is rarely necessary

"When the contact areas are accustomed to the pressure of the brace the patient is admitted to the hospital on the day prior to operation With recumbency the brace will feel loose It is not necessary to obtain any correction before the operation is performed The lateral pressure pad is advanced only if it is loose

"Operations were originally performed through the brace It is now removed on the night before surgery and the patient given a tub bath After completion of the operation the patient is returned to bed on a firm mattress The brace may be reapplied immediately or after he has responded The patient may be lifted in the prone position while one assistant spreads the pelvic band It is equally satisfactory to slip the brace on with the patient supine and then roll him over The brace provides postoperative immobilization of the grafted area Under opiates there is an increased likelihood of pressure sores Frequent inspection of the skin is necessary

After the operation the brace will be much too loose On the next day it should be extended above the circular band about half an inch the back a little more than the front to avoid hyperextension The deformity will be considerably diminished The release of muscles fasciae and ligaments contributes to this correction The brace is changed only to take up slack The turnbuckles and lateral pressure pad are advanced every day or two After each change the patient is instructed to raise his chin and occiput from the brace If he cannot do this the correction has been too rapid The lateral pressure pad should be entirely loose when the patient lies on the opposite side

"If the operation is performed in two stages the brace is removed in the operating room just before the second operation If the turnbuckles and side bars have been elongated to almost the limit they are replaced with longer ones This maintains the same length but provides for further extension By having the parts ready the work may be completed and the brace returned by the time the operation has been finished

Additional correction of the curve will be obtained easily after the second stage "Taking up slack should be continued for about two weeks after the completion of the operation The maximum correction will then have been obtained and only slight further adjustment is necessary as the child grows Symmetrical distraction should be used at all times There is no point in advancing one turnbuckle faster than the other The only result of such asymmetry would be to make unequal pressure on the head and iliac crests

"Temporary traction of one or both legs is occasionally useful in relieving pressure on the iliac crests This may well be combined with traction on the brace in a cephalad direction Lateral pressure should be made by advancing the lateral pressure pad There is less likelihood of overcorrection of the curve than if a bent jacket were used Further it is possible to watch the correction from day to day As the child gets up one has the benefit of clinical observation to check the degree of correction

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at the coccygeal level In some cases the plaster may have to be extended upward to include the occiput, and downward over both thighs to the knees The plaster shell is then removed and turned over, its inner surface will of course be asymmetric If the bed is to be used as a support, the inner surface is made smooth either by hammering the plaster ridges flat or by adding some plaster-of Paris paste For additional correction, about



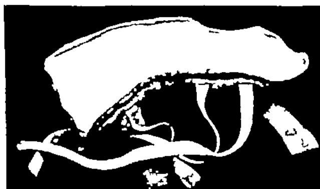
FIG 144 Corrective board and pegs (36)

half an inch of plaster paste may be added over the site of the convexity The brace maker then bakes it to obtain maximum hardness and mounts it on runners Retention webbing straps are affixed at the upper, middle and lower parts, to hold the patient in the desired position An apron may be used to assure a fixed position

Corrective Board and Pegs

This method of forcible correction with the spine in extension is chiefly for infants with congenital scoliosis it is simple painless and effective (Fig 144) The patient is placed on a board with many holes into which

and keep his muscles in good tone The exercises which may be taken in either the prone or supine position should at first be of the developmental and symmetric type and later of the corrective sort those involving the abdominal, back and neck muscles are particularly valuable



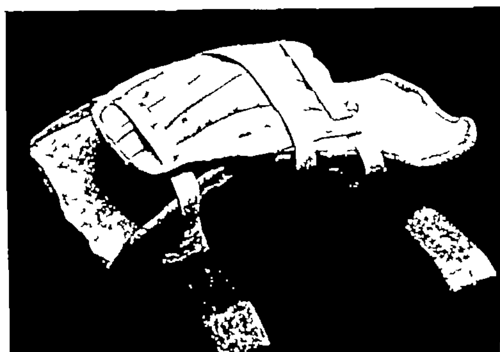


FIG 143 Plaster-of paris bed A (upper) Without apron B (lower) With apron

Preparation of Bed The patient is placed prone on a flat firm table After the back has been covered thoroughly with talcum powder plaster-of Paris bandages are spread over the back vertically horizontally and obliquely the layers being thoroughly incorporated by rubbing When the plaster is thick and hard enough it is trimmed across the neck around the shoulders, down along the chest and abdomen and across the buttocks

the shoulders and pelvis The aim of the method is to correct, simultaneously, the rotation and deviation of the scoliotic spine Correction is maintained by a plaster-of Paris jacket which is replaced at intervals when additional improvement is sought This method, like the others, eliminates to some degree the force of gravity, makes use of traction to obtain reduction of the curvature, and a plaster support for maintenance of correction

After-treatment of Forcible Correction

Once a curvature of the spine has been corrected, or, more accurately as soon as the maximum degree of improvement has been obtained, the patient should be provided with a supportive corset or brace which will hold the spine in the improved position Gymnastic exercises which will increase the patient s muscular strength and teach him to retain the improved position are an essential adjuvant during the months or years that the supportive apparatus is worn

It would be unreasonable to expect that a person who has worn a support for a year or two should suddenly be able to do without it The supportive apparatus is therefore dispensed with only gradually The support is first removed for a few minutes only and the patient is allowed to stand up without it Then a few simple exercises are performed without the apparatus These are gradually increased in number and variety until the patient is able to perform a regular course of exercises without the support of corset or brace. The supportive apparatus can then be discarded

Except when there is some cause for muscle imbalance and disturbed equilibrium scoliosis shows little tendency to increase after the age of 16 or 17 years As a rule therefore, supportive apparatus need not be worn after the period of growth is passed However examination at regular intervals roentgenograms, and measurement of the angles of the curvature should be continued for some time

Compensation Method

This method devised by Steindler (85 86), is based on the premise that the best one can do therapeutically in a structural scoliosis is to establish a good stance and proper balance by bringing the shoulders directly over the pelvis and the pelvis into such a position that the line of weight bearing and the center of gravity will fall in a vertical direction between the feet in standing and in the middle of the pelvis in sitting This, he believed could be accomplished by creating compensatory curves in the spine rather than by the use of forcible correction.

Treatment is divided into three periods (*1*) gymnastic exercises for mobilization of the nonrigid portions of the spine (*2*) maintenance of the

vertical pegs can be fitted The pegs should be so distributed as to cause three-point pressure For instance if the patient has a right dorsal curve, one peg is placed at the elevated left shoulder and another at the left side of the pelvis The trunk is then pushed over to the left, and a peg is inserted on the right side at the convexity The supine position eliminates the force of gravity as a deforming factor, and the three-point pressure applies a corrective force over the apex of the curve

Abbott Method

About 1911 Abbott (1a) concluded that he was obtaining unusually good results in treating scoliosis with the spine in flexion The extravagant claims for the effectiveness of his complicated system of treatment were later disproved but for a brief period Portland, Maine became a Mecca to hopeful orthopaedic surgeons The chief characteristics of the Abbott method are

(*1*) Patient is placed in a position of marked flexion in a specially designed apparatus.

(*2*) The jacket, applied in flexion maintains this posture of the body when the patient stands up

(*3*) Pelvis and shoulders are fixed by canvas bands

(*4*) Corrective pressure is exerted by canvas bands directly over the deformity

(*5*) Space is allowed in the jacket over the hollow parts especially in the back Pressure pads inserted over the chest in front besides tending to correct the deformity help to maintain and increase the flexion of the spine

With the exception of the position of the spine the principles of the Abbott method differ in no way from those of treatment with the spine in extension The results of the Abbott method of treatment were rather discouraging The improvements were no greater than with the simpler methods and the treatment proved extremely severe and was accompanied by many untoward sequellae, such as pain dyspnea prostration and in a few instances death. The popularity of the method was short lived and it is no longer used.

Galeazzi Method

Galeazzi (51) reported excellent results in 1929 from a method of forcible correction which he devised After preliminary mobilization of the spine by stretching appliances and gymnastic exercises forcible correction was obtained through a specially designed apparatus in which the patient remains in the prone position The particular feature of this corrective machinery is the opportunity for independent and regulated rotation of

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compensatory curves by plaster-of Paris jacket or by brace, (5) stabilization of the body alignment attained

Mobilization No relaxation of the rigid curve is attempted all mobiliza-

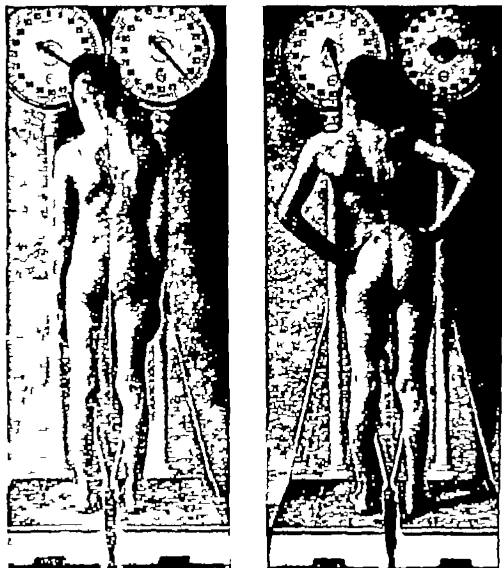


FIG 145 Effect of body shifting on weight measured on twin scales (86)

tion being directed toward the portions of the spine above and below the primary curve The compensatory curves are thus formed entirely from the movable and noncontracted sections of the spine

Both passive and active gymnastic exercises are used Passive mobilizing gymnastics include body swinging manipulation of the pelvis and exercises with all kinds of mechanical devices. Among the active gymnastic exercises are Klapp s creeping exercise and body shifting (Fig 145) In addition

setting-up exercises may be given, such as the asymmetric forward thrust or sally exercises, as well as general exercises of symmetric nature From 2 or 3 weeks to several months are required for complete mobilization of the lumbar and cervicodorsal sections and full development of compensatory curves

Fixation A plaster jacket stabilizes the compensation acquired during the mobilization period The jacket is applied in the upright position, with



A B

Fig 146 Compensation method (86) A Patient in traction resting with right buttock on support left leg abducted B Back and front view of completed jacket

the head held stable in a Glisson swing no other traction is used If the primary curve is a right dorsal one the patient stands with his left leg in about a 20 degree abduction or sits with his right buttock on a specially constructed seat which allows the left half of the pelvis to drop and the left leg to go into abduction (Fig 146A, B) The left arm is raised, the right arm lowered and the patient is asked to assume a position of self correction. The trunk is steadied by muslin straps or by an assistant who places his hands diagonally at the costal prominence front and back. Compensatory rotation can now be carried out either by stabilizing the rigid midportion of the spine and rotating the left half of the pelvis and left half of the shoulder girdle backward or by rotating the midportion,

which is being held fast, against both pelvis and shoulder girdle The important factor is that the rotation of the shoulder girdle and pelvis are in the opposite direction to the rigid curve This is the position in which the jacket must be applied. Since in a primary right dorsal curve the abduction of the left leg and the dropped left pelvis are essential for stabilizing the compensatory curves, the left thigh must be included in the jacket.

Jackets are changed every 2 to 4 weeks until it seems certain that compensatory curves have become permanently established (Fig 147) Depending upon the degree of compensation to be maintained, jackets are worn 1 to 5 months, or longer

Stabilization The decision whether to proceed to a spine-fusion operation after the jacket is dispensed with depends upon whether body balance can be maintained without it Steindler believes that in many instances operation is unnecessary But such cases must continue with muscle training for several years A supportive brace is worn until the muscles are properly developed The brace in principle resembles the jacket and has an extension which includes the thigh of the side opposite the main dorsal curve. It may be necessary to wear the brace for a year or longer

In the majority of cases, however a spine fusion is necessary for definitive stabilization

Further experience with the compensation method was reported by Steindler and Ruhlin (89) in 1941 Regarding indications and contraindications, they state

The compensation-derotation treatment is adequate when the following conditions are present

1 Complete lumbar compensation of a thoracic primary curve with horizontal pelvis and horizontal fifth lumbar vertebra as in a habitual scoliosis with a moderate curve

2 Complete lumbar compensation of the thoracic primary curve with horizontal pelvis but oblique fifth lumbar as in a non paralytic scoliosis with a straight upper thoracic spine and a moderate curve

3 A short and moderate thoracic curve with a straight upper and straight lumbar spine as in a congenital or habitual scoliosis in a patient who has passed the period of rapid growth.

4. A primary lumbar curve with a horizontal pelvis and a horizontal fifth lumbar as in a rachitic or congenital scoliosis [In brief when the two segments of the S curve are practically equal]

The compensation-derotation treatment is inadequate in the following cases

1 All paralytic cases with possibly a few exceptions of the mildest type

2. Severe cases of all ages and types which because of a rigid lumbar spine remain uncompensated.

3 All scolioses with oblique pelvis except those in patients close to the completion of growth.

4 All high thoracic or cervicothoracic curves not completely compensable

There are however some congenital high thoracic and cervicothoracic cases with congenital fusion which hold after conservative treatment

5 Congenital scoliosis with oblique pelvis and oblique fifth lumbar

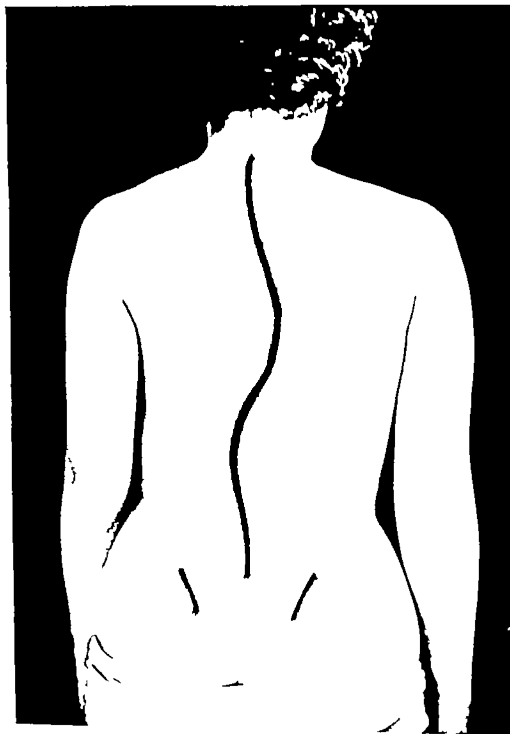


FIG 147 Compensated right dorsal scoliosis

which is being held fast, against both pelvis and shoulder girdle. The important factor is that the rotation of the shoulder girdle and pelvis are in the opposite direction to the rigid curve This is the position in which the jacket must be applied Since in a primary right dorsal curve the abduction of the left leg and the dropped left pelvis are essential for stabilizing the compensatory curves, the left thigh must be included in the jacket.

Jackets are changed every 2 to 4 weeks until it seems certain that compensatory curves have become permanently established (Fig 147) Depending upon the degree of compensation to be maintained jackets are worn 1 to 5 months, or longer

Stabilization The decision whether to proceed to a spine-fusion operation after the jacket is dispensed with depends upon whether body balance can be maintained without it. Steindler believes that in many instances operation is unnecessary But such cases must continue with muscle training for several years. A supportive brace is worn until the muscles are properly developed. The brace in principle, resembles the jacket and has an extension which includes the thigh of the side opposite the main dorsal curve It may be necessary to wear the brace for a year or longer

In the majority of cases however a spine fusion is necessary for definitive stabilization

Further experience with the compensation method was reported by Steindler and Ruhlin (89) in 1941 Regarding indications and contraindications, they state

The compensation-derotation treatment is adequate when the following conditions are present

1 Complete lumbar compensation of a thoracic primary curve with horizontal pelvis and horizontal fifth lumbar vertebra as in a habitual scoliosis with a moderate curve

2. Complete lumbar compensation of the thoracic primary curve with horizontal pelvis but oblique fifth lumbar as in a non paralytic scoliosis with a straight upper thoracic spine and a moderate curve

3 A short and moderate thoracic curve with a straight upper and straight lumbar spine as in a congenital or habitual scoliosis in a patient who has passed the period of rapid growth.

4 A primary lumbar curve with a horizontal pelvis and a horizontal fifth lumbar as in a rachitic or congenital scoliosis. [In brief when the two segments of the S curve are practically equal]

The compensation-derotation treatment is inadequate in the following cases

1 All paralytic cases, with possibly a few exceptions of the mildest type

2. Severe cases of all ages and types which because of a rigid lumbar spine remain uncompensated.

3 All scolioses with oblique pelvis except those in patients close to the completion of growth

4 All high thoracic or cervicothoracic curves not completely compensable

reached, the patient is ready for supportive treatment and gymnastic exercises or for a spine fusion

Results of Conservative Treatment

So far, no cure of a structural scoliosis has been reliably reported, there are no illusions on this point, although there is a hope for the future What then has conservative treatment accomplished? To repeat what has already been said the objects of treatment are (*1*) to prevent the deformity from increasing, (*2*) to reduce the curvature to the maximum degree, (*3*) to maintain the improvement

My personal preference is for treatment with the spine in extension, either by means of the corrective plaster jacket or by traction on the convex frame Such treatment has given good results in 70 to 80 per cent of my cases. But the important thing to be remembered is that the result is determined by the type of scoliosis being treated and not by the treatment Excellent results can be obtained in the mild and moderate types with any one of a variety of methods In severe scolioses, with marked rigidity and/or severe lateral tilt of the trunk, no procedure will accomplish much, and it is these which make up the 20 to 30 per cent of failures that grow progressively worse despite vigorous treatment

Steindler and Ruhlin (89) reported that 80 per cent of their conservatively treated cases were improved At the New York Orthopaedic Dispensary and Hospital (95) over 90 per cent of the cases are managed by conservative treatment and only 5 to 8 per cent require immediate or eventual surgery Such a statement coming from a hospital where surgery has been extensively used in scoliosis, is clear evidence that conservative treatment has given satisfactory results in the vast majority of cases

Smith (82) reported that of 1 408 patients seen between 1928 and 1935 only 19 per cent underwent surgery evidently 81 per cent did well under conservative treatment

Most reports on the treatment of scoliosis state that 10 to 20 per cent of the cases require operative treatment, from which one may conclude that in the remaining 80 to 90 per cent conservative treatment is satisfactory

Generally speaking favorable results can be expected in the following cases (*1*) single curves of mild or moderate degree (*2*) long dorsal short lumbar curves (*3*) mild S curves (*4*) moderate deformity in the lower half of the dorsal region and slight compensatory curve above or below this, (*5*) mild and moderate lumbar curves. Perhaps all good results are evidences of adequate compensation and the establishment of stability through muscle training

In 100 cases treated by the authors, spontaneous compensation had occurred in 30 compensation was established in 50 and no compensation occurred in 20 They found that the primary curve increased under conservative treatment only in patients before or early in the period of rapid growth but not in older patients When the curve did increase the compensation was not necessarily disturbed

Scoliosis in Adults

Some adults have mild curvatures in the dorsal or, more frequently in the lumbar region which have caused no symptoms and of which they are unaware These curvatures are discovered accidentally in the course of physical examinations for other conditions They require no treatment and the physician should take particular care not to divulge to the patient the existence of the scoliosis, the curvature is not apt to get worse and the patient would not benefit by the knowledge of its existence

There is another group of adults, especially women with mild lumbar curves who suffer persistent backache, sometimes accompanied by sciatica Reduction of physical activity and a low back support, such as a canvas reinforced belt or a brace, are usually effective in eliminating or reducing the pain In the acute phase temporary strapping of the back with adhesive plaster, local physical therapy, or even a supportive plaster-of Paris jacket may be used to advantage

In adult patients with a moderate or severe deformity in the dorsal region accompanied by pain in the thoracic region and/or in the chest and abdomen, a spine fusion is indicated if conservative treatment is without success

Maximum Potential Improvement

My observation of many hundred cases of structural scoliosis have convinced me that almost every curve can be reduced but that somewhere along the line of treatment even in cases of moderate degree, a stage of correction is reached beyond which it is impossible to advance no matter how much force may be used This is the stage of *maximum potential improvement* and it varies with the curvature and the individual patient It is easily recognized by the stationary character of the curvature as demonstrated by repeated roentgenograms One soon learns to recognize this point clinically and it is important to do so since thereby the patient is spared unnecessary treatment discomfort and expense and the surgeon unnecessary expenditure of energy

The foregoing applies to all forms of forcible correction ambulatory as well as recumbent. Once the point of maximum potential improvement is

Chapter XII

SURGERY IN STRUCTURAL SCOLIOSIS

No matter how well the patient may tolerate the treatment, or how expert and persistent the surgeon may be, in a definite minority of cases the deformity continues to increase, sometimes attaining a conspicuous severity with more or less disabling backache and a variety of functional disorders. Orthopaedic surgeons have sought effective means to curb or correct this type of scoliosis, their attempts naturally being in the direction of operative intervention.

The first surgical efforts were of a cosmetic nature. Volkmann (93), in 1890 suggested that the scoliotic deformity might be reduced by resecting the ribs on the convex side, and Casse in 1893, Hoffa in 1896 (43 & 44) and Hoke in 1903 performed this operation. Whitman, Colonna, Kahle and I, among others, did a rather large number of cosmetic rib resections in the 1920's at the Hospital for Ruptured and Crippled in New York City with satisfactory results. I have continued to make use of this operation in selected cases to the present date and am satisfied with the results. Hibbs (38, 39, 40, 41 & 42), encouraged by the results of the spine fusion operation for Pott's disease, began to use this operation to stabilize the spine in scoliosis. Albee (3, 4) and many others followed his lead, and today the operation is a common one for scoliosis. More recently von Lackum and Smith (94) have attempted to obtain a cure by removing a hemivertebra in cases of congenital scoliosis. Undaunted by past failures and encouraged by the modern improved surgical technic, orthopaedic surgeons are now seeking to alter the structure of the wedge vertebrae by unilateral retardation of their body growth. This has been attempted through unilateral epiphyseodesis or unilateral vertebral body stapling of the vertebrae at the apex of the curve on the side of the convexity.

As practiced today, the surgical procedures for scoliosis are: (*1*) Spine fusion, (*2*) rib resection, (*3*) removal of a hemivertebra, (*4*) fasciotomy, myotomy and capsulotomy, (*5*) laminectomy when scoliosis is complicated by paraplegia, (*6*) unilateral epiphyseodesis, (*7*) vertebral body stapling for controlled growth, (*8*) pleural decortication for thoracogenic scoliosis.

Spine Fusion

The aim of a spine-fusion operation in scoliosis is to strengthen the resistance of the spine against deforming forces. This may be accomplished

Poor results or no improvement at all must be expected in the following cases, (1) curvatures with sharp angulation of the ribs, the so-called razor back deformities, (2) high dorsal or cervicodorsal curves, (3) marked distortion in the lumbar region, (4) severe S curves, with the dorsal deformity equal in extent and degree to that of the lumbar region.

When all is said and done however, let no one doubt that in the majority of structural scolioses, any one of the many well tested conservative methods can be used successfully provided that expectations are kept within the bounds of the known therapeutic limitations and the specific aims of treatment.

Faced with a choice of treatment from among several each of which yields good results the student or novice may be in doubt as to the method of choice for a particular patient His choice will in part depend on the training he has received One trained in and adept with method *A* will obtain better results with it than with method *B* All methods use practically the same corrective principles only the manner of applying these principles differs. The results are about the same whatever method is used, and depend upon the tenaciousness and length of time that treatment is continued.

Hereditary scoliosis has a tendency to follow a definite familial pattern, both in type and degree A prophylactic spine fusion therefore is justified in patients with scoliosis whose family history reveals a tendency to severity

A cervicodorsal scoliosis does not lend itself to successful treatment by corrective measures, including the Calot jacket, the Wullstein jacket, or the Milwaukee brace Some slight improvement may result if the head is included in the corrective apparatus, whether plaster-of Paris or steel brace Early spine fusion should be performed, in the hope, not always realized that the deformity may remain at the stage in which it was found

Persistent backache is a common symptom in adults with scoliosis If there is a moderate or severe deformity in the dorsal region, and a variable degree of backache in the thoracic region and/or pains in the chest and abdomen which are not relieved by support of the back, a spine fusion is indicated

Contraindications Spine-fusion operations should not be performed in the following cases (*1*) when conservative treatment is successful, (*2*) when the deformity is mild, (*3*) when the deformity is stationary, (*4*) if the patient is asthenic, (*5*) if the patient is very young Some orthopaedic surgeons believe that all scoliotic spines require fusion. Obviously, this is an erroneous belief since about 80 per cent of the cases treated by conservative methods do well. Great patience is essential in the management of a scoliosis, there is no royal road or short cut to successful arrest of the deformity The period of treatment (including observation) is often a matter of 5 to 10 years nor can it be abbreviated with even a semblance of certainty, by surgery In fact in most large scoliosis clinics only about 10 per cent of the patients undergo operation.

Spinal Area to Be Fused When it is possible to identify the primary or basic curve that is obviously the part of the spine to be fused But frequently such identification is impossible as in an idiopathic right dorsal left lumbar S curve in which the dorsal and lumbar segments are about equal and there is nothing to show which part of the curve occurred first It seems better therefore, to think in terms of the major or paramount curve that is the segment of the curve which is most prominent and salient. This is the part of the spine that should be fused

It is generally agreed that the entire major curve, from the transitional vertebra above to the transitional vertebra below should be included in the fusion procedure The transition areas are readily recognised when the patient is on the operating table and all posterior arches of the major curve are exposed in a one-stage operation Some surgeons particularly those who use the Risser method prefer to do a fusion operation in several stages these require more accurate identification of the vertebrae to be fused.

by obtaining the union of several or many vertebrae, usually along their posterior arches including the intervertebral articulations. Since this stabilizes a segment of the spinal column, it is hoped that whatever improvement of the curvature has been attained by corrective measures will be maintained and that a relapse to a previous state will be prevented. The fusion even when successful is not an absolute guarantee against a recurrence of the deformity for the largest part of the vertebral column (the part *in front of the apophyseal joints*) remains unchanged and what is more important the fusion does not eliminate the deforming factors. In my opinion the most that can be expected from a spine fusion is strengthening of the spine against increasing deformity In fact even if the spine were completely ankylosed, it could like any solid rod as the bough of a tree still become bent Nevertheless, a fused spine is undoubtedly stronger than the normal segmented and jointed spinal column and the therapeutic value of spine fusion in scoliosis is unquestionable

Indications A spine fusion for structural scoliosis is indicated in (*1*) paralytic scoliosis, when conservative treatment is inadequate (*2*) progressive deformity (*3*) failure of conservative treatment in nonparalytic scoliosis (*4*) patient with history of severe familial scoliosis, (*5*) cervicodorsal kyphoscoliosis, (*6*) persistent back pain with a moderate or severe dorsal curvature in adults.

Judging by statistics from various clinics about 50 per cent of patients with *paralytic scoliosis* require a spine fusion. There is general agreement that postpoliomyelitic scoliosis is apt to grow severe as a result of muscle imbalance the frequently severe contractures, and the marked trophic changes in both muscles and bones. At the slightest sign that conservative treatment is proving inadequate, a sufficiently extensive spine fusion should be performed. More than in any other type of scoliosis, delay may lead to disastrous and irreversible results. The spine fusion should be preceded by the maximum obtainable correction of all deformities, especially of a fixed pelvic obliquity Reinforcement of a partially or completely paralyzed abdominal wall by subcutaneous fascial ligaments between the costal cage and the iliac crests will at least aid the general rehabilitation of the patient (56) and correction or improvement of the paralytic defects in the upper or lower limbs is important

Rachitic scoliosis is now fortunately infrequent because of the low incidence of rickets. This type of scoliosis tends early to develop into a severe and markedly rigid deformity If there is no evident improvement with conservative treatment and the curvature shows signs of growing worse a spine-fusion operation should not be delayed. Actually this is the safe attitude toward any type of scoliosis. Lack of improvement during treatment in a patient under 14 years of age is a danger signal calling for a spine fusion to reinforce the resistance of the spinal column

Hereditary scoliosis has a tendency to follow a definite familial pattern, both in type and degree. A prophylactic spine fusion therefore is justified in patients with scoliosis whose family history reveals a tendency to severity.

A *cervicodorsal scoliosis* does not lend itself to successful treatment by corrective measures including the Calot jacket, the Wullstein jacket, or the Milwaukee brace. Some slight improvement may result if the head is included in the corrective apparatus, whether plaster-of-Paris or steel brace. Early spine fusion should be performed in the hope, not always realized, that the deformity may remain at the stage in which it was found.

Persistent backache is a common symptom in adults with scoliosis. If there is a moderate or severe deformity in the dorsal region and a variable degree of backache in the thoracic region and/or pains in the chest and abdomen which are not relieved by support of the back, a spine fusion is indicated.

Contraindications. Spine-fusion operations should not be performed in the following cases: (*1*) when conservative treatment is successful; (*2*) when the deformity is mild; (*3*) when the deformity is stationary; (*4*) if the patient is asthenic; (*5*) if the patient is very young. Some orthopaedic surgeons believe that all scoliotic spines require fusion. Obviously this is an erroneous belief, since about 80 per cent of the cases treated by conservative methods do well. Great patience is essential in the management of a scoliosis; there is no royal road or short cut to successful arrest of the deformity. The period of treatment (including observation) is often a matter of 5 to 10 years, nor can it be abbreviated with even a semblance of certainty by surgery. In fact, in most large scoliosis clinics only about 10 per cent of the patients undergo operation.

Spinal Area to Be Fused. When it is possible to identify the primary or basic curve, that is obviously the part of the spine to be fused. But frequently such identification is impossible, as in an idiopathic right dorsal left lumbar S curve, in which the dorsal and lumbar segments are about equal and there is nothing to show which part of the curve occurred first. It seems better, therefore, to think in terms of the major or paramount curve, that is, the segment of the curve which is most prominent and salient. This is the part of the spine that should be fused.

It is generally agreed that the entire major curve from the transitional vertebra above to the transitional vertebra below should be included in the fusion procedure. The transition areas are readily recognized when the patient is on the operating table and all posterior arches of the major curve are exposed in a one-stage operation. Some surgeons, particularly those who use the Risser method, prefer to do a fusion operation in several stages; these require more accurate identification of the vertebrae to be fused.

Risser (74), in 1948, thus described the fusion area

"The fusion area should cover the entire area of the curve that is from neutral or least rotated vertebra above to neutral vertebra below and in the x ray showing correction these vertebrae should be parallel If there is no well-defined compensatory curve below fusion should be carried down the full extent of the lower arm of the correcting curve This is especially true if there is lateral body shift to the side of convexity

Ferguson (20 27) states that the area of fusion must extend from "end vertebra to end vertebra of the primary curve and it must be determined

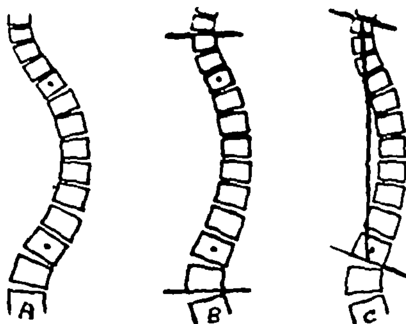


FIG 148 Diagram of the vertebrae in scoliosis and selection of fusion area dots indicate the end vertebrae of minimum fusion area B ideal fusion area indicated by bars C Improperly selected fusion area indicated by bars (26)

before the curve is corrected If by including one or two additional vertebrae an ideal fusion area is created (Fig 148) fusion may extend beyond the minimum area and should usually be made except in cases with rigid compensatory curves, or if the total fusion area becomes so great as to create an undue surgical risk The ideal area is one "including the minimum fusion area but ending at vertebrae in which the superior surface of the superior vertebra and the inferior surface of the inferior vertebra are parallel to each other and at right angles to a line joining their centers

It should be noted that Ferguson emphasizes two points fusion should extend from the uppermost to the lowermost horizontal or transitional vertebra and fusion should not extend into the compensatory curves if they are rigid and the vertebrae are structurally deformed, for the body in the

upright position would then be unable to find a good balance and equilibrium, and would be asymmetric To avoid this, von Lackum and Miller (96) are using transection jackets in an attempt to obtain simultaneous reduction of the major and secondary curves, and thus preclude overcorrection and trunk asymmetry Their method is actually one of traction in vertical suspension or on a convex frame, which duplicates the procedures I prefer and duplicates Steindler's compensation method, in all of these procedures overcorrection of the compensatory curve is avoided by doing a spine fusion through a support which maintains the correction

The problem of a spine fusion which aims to *fuse, strengthen and stabilize* a larger or smaller segment of the spine, cannot be settled with *mathematical accuracy, as one would the fittings of a machine* Much about the anatomy, physiology, and mechanics of the spine is not fully understood and cannot be regulated For example, in a right dorsal curve involving 8 vertebrae fusion of the 3 or 4 vertebrae at the apex is manifestly inadequate nor when the spine is flexible is it advisable to reduce the dorsal curve by establishing marked compensatory curves in the lumbar and cervical areas and fuse these areas since a marked opposite *body asymmetry would then result It is for these very reasons that I find* treatment in a straight jacket or by traction on a convex frame or by the Steindler compensation method preferable These methods reduce the existing trunk asymmetry and do not introduce a new or even worse asymmetry This factor formed the greatest objection to the Abbott method, which often resulted in a marked new distortion of the trunk, and it is a potential hazard in the Risser method

Last but not least it should not be forgotten that a spine fusion is only one element in the treatment of a scoliosis and that the primary objective is to obtain an improved appearance of the back and a stable stance One therefore estimates the extremities of the major curve after a satisfactory and maximum reduction has been obtained and performs the fusion between these extremities of the curve including one transitional vertebra at each end for the sake of additional security

Types of Spine Fusion The basic procedure is the Hibbs type of fusion This has now been modified and strengthened by the addition of an autogenous or homologous bone graft or of a beef bone graft Some surgeons use massive grafts others chip grafts and still others osteoperiosteal ribbons obtained from the tibia or ilium The original Hibbs technic called for a bilateral fusion and many still follow this procedure More than 30 years ago I became convinced that it was not only very difficult but virtually impossible to carry out the Hibbs technic to the letter on the convex side of the curve in a severe scoliosis, and ever since I have been doing unilateral spine fusions on the concave side with a beef bone graft to reinforce the

fusion (52, 53, 54) My results compare favorably with those of the bilateral fusion The unilateral fusion has the added advantage that it permits an extensive one-stage procedure which includes all the vertebrae of the major curve

Once it has been decided that operative fusion of a scoliotic spine is advisable my program is as follows (*1*) traction on a convex frame until the maximum potential improvement has been obtained, (*2*) fusion of the major curve (*3*) postoperative rest in bed, usually for 2 weeks until the patient has completely recovered from the operation and the stitches have been removed (*4*) return to the convex frame and traction for 6 to 8 weeks (*5*) application of a supportive plaster jacket which is worn for 6 to 12 months (*6*) jacket replaced by a celluloid corset which is used until the treatment and observation are completed at the termination of puberty by which time the danger of further increase of deformity is over or relatively slight

Beef Bone Grafts in Spine Fusion

When some thirty-odd years ago bone grafts began to be used in spine fusions for tuberculous spines and in the repair of fractured hips, it was generally accepted that autogenous bone grafts were preferable to those of foreign bone Some believed that when a segment of tibia was transferred to the spine hip, or elsewhere the graft remained alive and hence would not only survive but even grow Others including myself have held that the graft dies when it is removed from its donor bone and severed from its blood supply Obviously this must be true of bone removed from the human body and preserved under refrigeration for many weeks before it is used as a graft

While autogenous or homologous bone is likely to take more readily and be more easily and rapidly incorporated by the human skeleton than heterogenous bone there are a number of advantages in using heterogenous bone grafts. (*1*) A beef bone graft can be prepared long in advance of operation so that a graft of the exact size thickness, and curvature needed is available without delay thus reducing the operating time This is an important consideration in a spine-fusion operation (*2*) It makes possible a graft of considerable thickness. This supplies the spine with a means of retaining the correction previously obtained and provides rigid resistance for the spine against recurrence of deformity (*3*) It spares the patient the additional trauma and shock incidental to removal of a graft from the tibia ilium, or ribs.

When beef bone is inserted into the spine the osteolytic activity of the host bone gradually fragments the graft until it is adsorbed and replaced by new living bone Depending on the size and thickness of the graft several years may elapse before the beef bone is completely absorbed (Fig 149)



Fig 140 Beef bone spine fusion A B and C Roentgenograms illustrating various degrees of fragmentation and replacement by new bone D Graft replaced by solid mass of new bone

In one of my cases there appeared to be remnants of the original graft 6 years after its implantation As a rule, however in spine fusions the beef bone graft disappears in about 2 years

The one disadvantage I encountered in using beef bone grafts occurred in a small percentage of cases in which thick cortical bone was used for the graft Apparently this bone is too dense to be penetrated by invading blood vessels and therefore occasionally acted as a foreign body and had to be removed I therefore now use only bone that is composed of both cancellous and compact bone since these grafts are more readily invaded by blood vessels and replaced by new bone I have not had to remove a single graft since I stopped using thick cortical bone

The ultimate result in a beef bone spine fusion is a massive deposit of new bone uniting the operated vertebrae (Fig 149D) The graft is usually placed on the concave side of the curve so that the new bone not only fuses the vertebrae but forms a strong strut between the extremities of the major curve of the spine (In a few cases I have used two grafts placing them on either side of the spinous processes Since this prolonged the operation and had no specific advantage I now use only one graft placed on the concave side of the curve) Once the new bone is deposited, it remains permanently I have seen no case in which it has become absorbed or fragmented It may not always prevent a further increase of the curvature, but neither does an autogenous bone graft spine fusion Pseudoarthrosis probably occurs after the use of beef bone as after a graft of autogenous bone but I have no data as to the frequency of such occurrence

Preparation of Beef Bone Grafts The beef bones used for grafts are the shin bones, iliac bones and ribs. These bones are obtained from the hospital kitchen After being freed of all soft tissue they are boiled for an hour and then cut with an electric saw into 6- to 10-inch lengths, ¼ to ½ inch in width and about the same in thickness. The grafts are then placed in a tall jar (Fig 150) filled with 70 per cent alcohol where they will keep indefinitely Grafts that have been boiled prior to operation but have not been used can be replaced in the jar with alcohol and used some other time since boiling in no way spoils the graft

Preoperative Treatment

When a patient is lying on his back, with muscles relaxed weight bearing eliminated and the pull of the force of gravity removed the curve is reduced somewhat in all but the severest types of scoliosis. Royal Whitman (98) therefore suggested that prior to operative fixation of the spine the patient should be placed on a convex frame for several weeks so that some improvement would be obtained before the operation This procedure was first used at the Hospital for Ruptured and Crippled and since 1928 at

the Hospital for Joint Diseases, both of New York City For the description of treatment by traction on a convex frame see page 213



Fig 150 Glass jar containing prepared beef bone grafts

Soon after instituting this treatment it was found that this simple and relatively painless method resulted in the maximum potential improvement in a few weeks as compared to the many months or even years required

when plaster jackets are used I feel justified in asserting that traction on a convex frame will result in the maximum potential improvement in 4 to 8 weeks in every case The decision as to when this point is reached in any given case depends upon the surgeon s knowledge as to the amount of change that may be expected and roentgenographic proof that increase in weights and traction no longer lead to further reduction of the curvature. The patient is ready for operative fusion of the spine when this point has been reached

Preparation for Operation

Three days before operation traction is released and massage is stopped but the patient remains on the frame On the first day the patient s back is shaved washed with soap and water and a sterile dressing is applied over the entire back. On the next day the back is again bathed and covered with a sterile dressing On the morning of the third day if the operation is to be in the afternoon the back is painted with tincture of iodine if the operation is to be in the morning the iodine is used the night before The sterile dressing which is then applied is not disturbed until the patient is on the operating table During the entire three days the patient is on a liberal carbohydrate diet, this usually prevents postoperative acidosis. Fluids are given liberally and may be taken up to 6 hours before operation No cathartics are given if there is constipation an enema is given the night before the operation.

Several beef bone grafts of the desired length, curve and thickness, are selected from the supply on hand and boiled in the steriliser with the instruments

The precautions in preparing the patient s back and the beef bone grafts are taken in order to assure asepsis Possibly some of the details are not indispensable but they have served me well in none of the patients that have undergone spine fusion has there been any postoperative infection other than an occasional irritation about a stitch hole

Operation

My procedure is a combination of the technics of Hibbs, Albee and Forbes. A vertical incision (Fig 151) of the desired length is made over the region to be fused and is deepened down to the deep fascia The periosteum over a single spinous process is incised and elevated from the underlying bone on the concave side as far as the middle or extreme end of the transverse process. Bleeding is controlled by packing with strips of gauze This is done with the periosteum of every spinous process in the wound (Fig 152) The small articulations between the vertebrae are then scarified With a curved chisel small pieces of bone are elevated from the laminas and

laid across the interlaminar spaces (Fig 153) (I have found the ordinary chisel with a straight shank difficult to use in the presence of pronounced deformity and have therefore devised a curved chisel with an elbow (Fig 154), it is particularly serviceable in gaining access to the deeper parts of the wound) The spinous processes of the 2 upper and the 2 lower

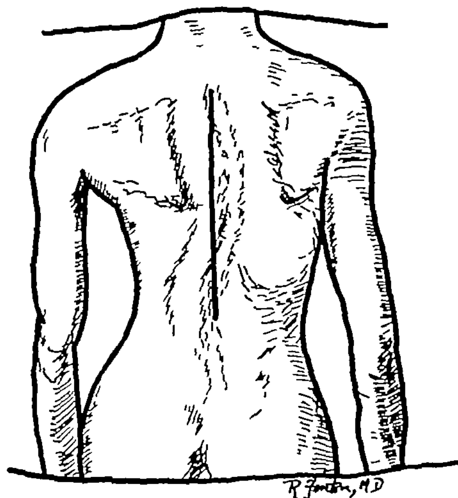


Fig 151 Incision for spine fusion note that the incision is in a straight line and does not follow the line of spinal curvature

vertebrae are split as in the Albee operation The graft is then placed in the wound (Fig 155) in contact with the laminas on the concave side of the curve, and the ends of the graft are imbedded between the split segments of the upper and lower spinous processes The remaining spinous processes are split into 3 or more segments each (Forbes's method) These are spread out laterally (Fig 156) and turned down over the graft This creates a wound with exposure of a large mass of bleeding bone with which the graft is brought into intimate contact The periosteum and muscles are sewed up by a single row of interrupted chromic catgut sutures. The deep

fascia and subcutaneous tissue are closed with separate layers of catgut sutures and the skin is closed with a continuous silk suture A sterile dressing is applied securely and the patient is returned to bed.

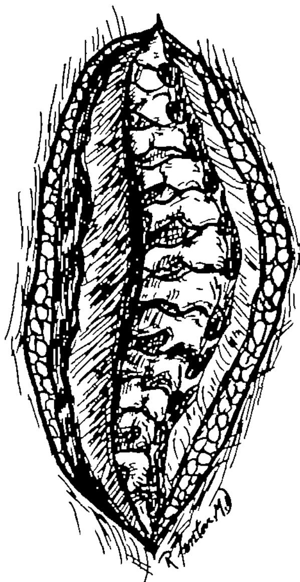


Fig 152 Spine fusion exposure of laminas on concave side of the curve for unilateral spine fusion.

The chiselling of bone from the laminas is apparently the part of the operation which causes the greatest amount of shock, for at this time the pulse quickens by 10 to 20 beats. It is advisable therefore to have the patient in rather deep narcosis at this point in order to minimize the effect of the trauma. As soon as the wound is ready for suturing anesthesia is stopped and administration of oxygen is begun this helps

patient to regain consciousness and reduces the degree of shock Saline solution is administered intravenously during the course of the operation as well as a minimum of 500 cc of blood a like amount is administered postoperatively, if indicated By repeated weighing of the blood soaked

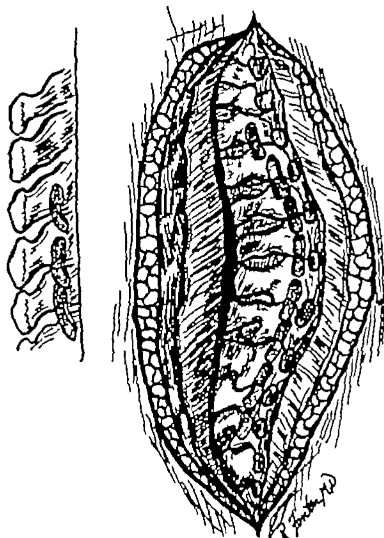


Fig 153 Spine fusion laminas exposed on concave side of the curve slivers of bone elevated from laminas and placed across interlaminar spaces

sponges, it has been estimated that the blood lost during operation amounts to 350 to 700 cc.

At best a spine fusion is a severely traumatic procedure and it is therefore imperative that the trauma be reduced to a minimum Retraction is necessary but intermittent pulling and jerking at the tissues can be avoided Reflection of the tissues away from the posterior arches of the vertebrae is an unavoidable trauma but if a sharp instrument is used and the strokes are well planned the trauma can be minimized In Agnew's

fascia and subcutaneous tissue are closed with separate layers of catgut sutures and the skin is closed with a continuous silk suture A sterile dressing is applied securely, and the patient is returned to bed.

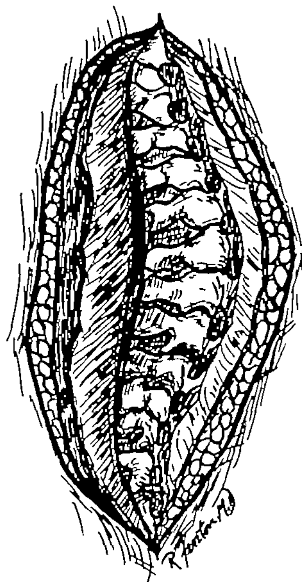


Fig 152 Spine fusion exposure of laminas on concave side of the curve for unilateral spine fusion

The chiselling of bone from the laminas is apparently the part of the operation which causes the greatest amount of shock for at this time the pulse quickens by 10 to 20 beats It is advisable therefore to have the patient in rather deep narcosis at this point in order to minimize the effect of the trauma. As soon as the wound is ready for suturing anesthesia is stopped and administration of oxygen is begun this helps

technical skill I have had occasion to observe that surgeons who approach without hesitation an arthrotomy of the knee or a hip arthroplasty will sometimes hesitate to perform a spine fusion for scoliosis Possibly some orthopaedic surgeons are not particularly interested in scoliosis while

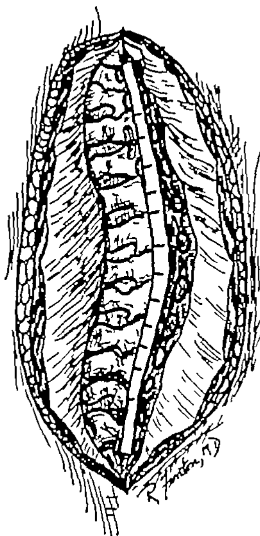


Fig 155 Spine fusion graft placed on concave side of the curve and fixed to the two upper and the two lower split spinous processes

others feel a lack of special aptitude for this particular procedure In this as in all surgical problems each surgeon's conscience must be his guide

Postoperative Care

No matter how rapidly or how gently the operation is performed, the patient is usually pale and his pulse is weak and by 20 to 30 beats more rapid than normal by the time the operation is finished The patient is

words the tissues should be treated *lovingly* certainly a most desirable practice in a spine fusion operation. I have found it advantageous before starting a spine fusion to emphasize as much for myself as for my assistants the need for gentleness during the whole operation.

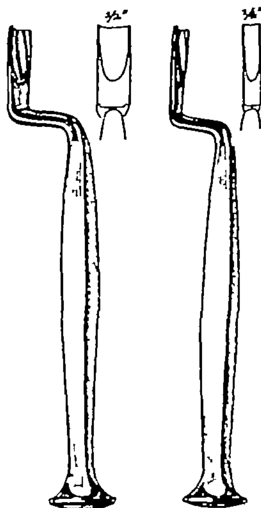


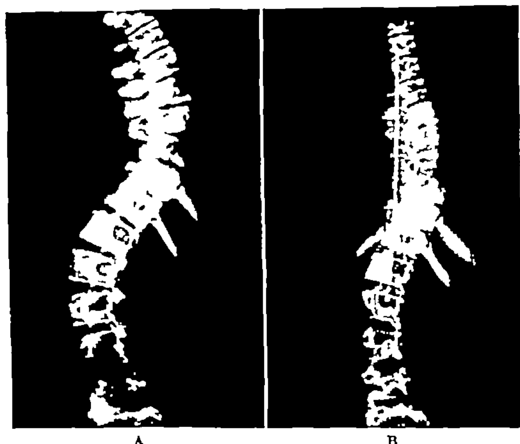
Fig 154 Spine fusion curved chisels ½ inch and ¼ inch wide each with an elbow the elbow facilitates elevating slivers of bone from the laminae

Since a spine fusion is a lengthy procedure under the best of circumstances, it should be performed as expeditiously as possible without sacrificing thoroughness Complicated procedures such as a rib resection and a *spine fusion in one stage* should be avoided a *spine fusion is* eminently an elective procedure and does not warrant inordinate risks. Generally the operation lasts an hour or a little longer

Like other major procedures in orthopaedic surgery a spine-fusion operation requires an exact knowledge of the local anatomy and a definite

at the apex of the curve on operation (presumably for increasing deformity)

Although a pseudoarthrosis is not necessarily the sole factor, it may along with other factors, be responsible for an increase in the curvature following a spine-fusion operation The signs of a pseudoarthrosis are (*1*) increasing curvature (*2*) mobility of spine in operated area, (*3*) localized back pain, (*4*) localized tenderness (*5*) roentgenographic evidence of lack



A B

FIG 158 Structural scoliosis treated by traction on a convex frame and beef bone spine fusion A Before treatment B After treatment

of continuous vertebral fusion None of the signs is pathognomonic, not even the last mentioned in which linear rarefaction is assumed to indicate lack of bony union

Increase of the curvature may be a natural phenomenon especially if the patient is in the last period of rapid growth Mobility of the spine after a spine fusion operation cannot always be established with certainty especially clinically the most certain method is to take anteroposterior and lateral roentgenograms with the body in various positions similar to those made in a case of potential herniated intervertebral disk. Localized pain and

In my own experience the correction has held in 70 to 75 per cent of the cases. Figures 157 158 and 159 illustrate the marked improvement that may be obtained by a judicious combination of conservative treatment with a spine fusion operation In the case illustrated by Figure 159 the cosmetic improvement was enhanced by a rib resection

Many surgeons have assumed that the postoperative relapse or increase

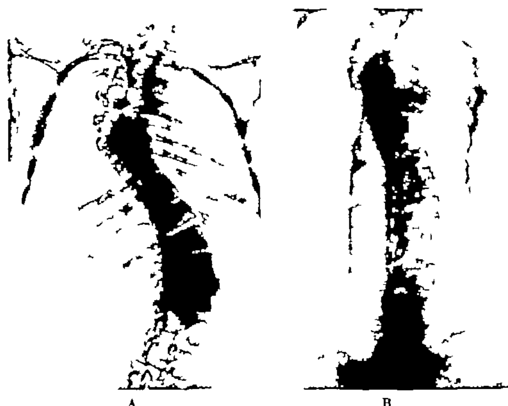
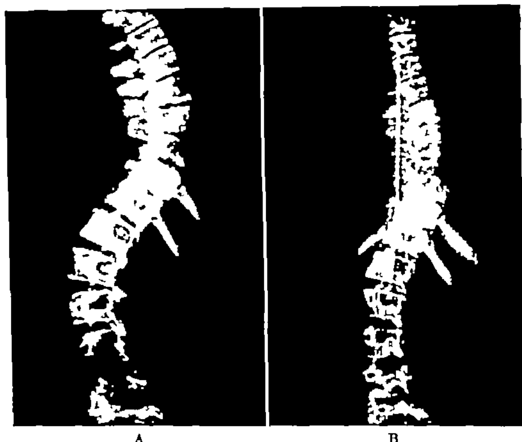


FIG 157 Roentgenograms showing the reduction of a severe structural scoliosis and the maintenance of improvement by a beef bone spine fusion A Before operation B After operation

of the deformity that occurs in 25 to 30 per cent of the patients who have undergone a spine-fusion operation is due to a lack of complete fusion or a pseudoarthrosis in the operated area. While this is entirely possible, I do not believe that a pseudoarthrosis need occur in order for the deformity to increase a spine whose posterior arches are fused is a solid rod and such a rod can become deformed In a number of patients on whom I have operated for a second time because of increasing deformity vertebral fusion in the operated area was intact in other words there was no pseudoarthrosis. Hibbs some time ago called attention to the fact that in a *certain percentage* of cases he had found spontaneous fusion of the vertebrae

at the apex of the curve on operation (presumably for increasing deformity)

Although a pseudoarthrosis is not necessarily the sole factor, it may, along with other factors, be responsible for an increase in the curvature following a spine fusion operation The signs of a pseudoarthrosis are (1) increasing curvature (2) mobility of spine in operated area, (3) localized back pain, (4) localized tenderness (5) roentgenographic evidence of lack



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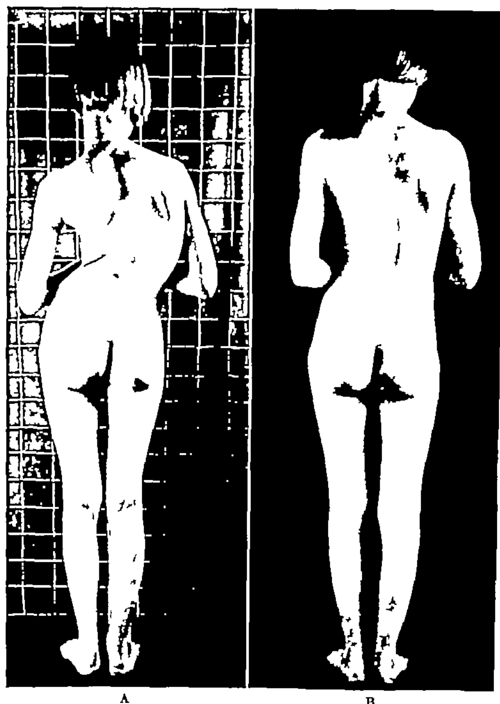


FIG 159 Cosmetic result from spine fusion and rib resection in a paralytic scoliosis A Before operation note sagging and shifting of trunk to the right and the marked rotation and prominence of the ribs on the right side B After operation (Courtesy of Dr Buchman.)

tenderness are subjective signs of uncertain value An area of rarefaction in the new bone deposited postoperatively is by many surgeons regarded as very significant of lack of fusion It seems to me an unreliable sign the roentgenogram shows flat shadows of bone and an area of rarefaction may mean not an absence of bone but merely less bone than in adjacent areas. However, when all or several of the signs are present, the occurrence of a pseudoarthrosis may be assumed An exploratory operation is then warranted in the hope of finding incomplete fusion the repair of which may help arrest the progress of the deformity

Effect on Growth

In my experience with spine-fusion operations in growing children, there has been no substantial if any, retardation of growth It has been claimed that the fusion of the posterior arches is bound to alter the pressure on the vertebral epiphyseal plates and that the vertebral bodies may therefore show some morphologic alteration That may possibly be so but I am certain that the change in the vertebral bodies has no clinical effect on the spine or its curvature (34) Of a group of 40 children who had undergone spine fusion and had been observed for 1½ to 6 years postoperatively 35 had grown 2 to 6 inches taller 3 of the remaining 5 patients were already tall and 2 had severe fixed deformities As a matter of fact this continued growth constitutes a hazard for retaining the correction in the curvature and makes necessary continued support of the back until the sixteenth or seventeenth year of life

Cosmetic Rib Resection

Indications These are fairly clear cut (*1*) sharp angulation of the ribs, not merely a rounded prominence (*2*) patient s insistence for an improved appearance When the angulation of the ribs is sharp, removal of sufficient rib tissue will reduce the height of the back on the operated side by as much as 1½ inches, thus greatly reducing the asymmetry of the back But when the backward projection of the ribs is only mild the asymmetry will not be much improved by rib resection and the operation is not warranted In every case the patient must be fully informed of just what the operation will accomplish so that he will have no illusions about a cure

Contraindications Absence of marked rib deformity extreme deformity of the trunk and conditions making the patient a poor operative risk are all contraindications. The operation will accomplish nothing in either the mild scoliosis or in the razor back deformity And since the operation is eminently an elective one it should obviously not be undertaken in the presence of cardiac decompensation or other circumstance making for poor operative risk

Operation As now practiced the operation consists of the removal of 3 to 4 inches of the proximal portion of each of 5 to 8 ribs on the convex side of the curvature, i e, those segments of the ribs which are mainly involved in the backward projection and angulation of the chest It is a relatively simple partial subperiosteal resection of the ribs and 5 to 8 ribs can be operated at one session There is a moderate amount of bleeding from the cut subcutaneous tissue and muscles, but the bleeding vessels are *small and easily seen and the bleeding is readily controlled Shock is rare* The one danger which can usually be avoided, is puncturing the pleura If the pleura is punctured, the hole should be closed immediately with some muscle tissue the only result of the misadventure is some embarrassment of respiration not serious and entirely temporary I have seen no permanent damage from such accidental puncture of the pleura.

The postoperative care is most important After the ribs are resected a soft easily compressed mass remains at the operative site If there is no operative shock the patient is placed on his back immediately after the operation or within a day or two He should remain in this position, except for the brief interruptions necessitated by hygienic care, meals, and the like for 3 to 4 weeks The patient should preferably lie on a rigid surface a board slipped under the mattress and a large felt pad applied over the operated area will accomplish this The stitches are removed on the eighth to the tenth postoperative day The ribs regenerate rapidly but are flatter and less angulated and the convexity of the back is more pleasing than before operation (Fig 160)

Removal of a Hemivertebra

As has already been pointed out in scoliosis treatment has been applied indirectly by traction on the head and pelvis traction or pressure on the ribs on the convex side of the curve positioning of the trunk and so forth No direct attack, such as is made in the case of bowlegs, knock knees, or epiphyseal slipping at the hip was attempted on the vertebrae at the apex of the curve because of the inaccessibility of the vertebrae With the great strides which surgery has made in recent years, it is not surprising that an attempt should have been made to reach and correct by surgery the wedging at the apex of the curve.

Von Lackum and Smith (94) who attempted this procedure, after operating on 10 patients (5 with ordinary scoliosis and 5 with scoliosis caused by a hemivertebra) came to the following conclusions

"1 Removal of the body and posterior arch of a hemivertebra is feasible in the lumbar region of the spine and is the only means of correcting a lateral curvature caused by this anomaly This should be supplemented by a spine fusion operation

2 The operation should be done in two stages, the first consisting of removal of the vertebral body through a lateral lumbar incision with a retroperitoneal approach The posterior arch should then be removed subperiosteally through a dorsal midline incision

3 This operation may be used also in certain selected cases of severe lateral curvature in the lumbar region not caused by hemivertebrae

4 Removal of a vertebral body in the dorsal region is impracticable because of the difficulty in exposing the body and the danger from hemorrhage and shock

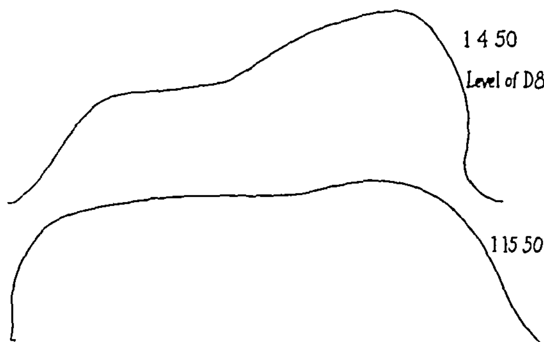


Fig 100 Tracing of back at the level of the eighth dorsal vertebra before and after rib resection

Compere (22) performed the operation on two patients, and reached the following conclusions

1 The standard methods used in the treatment of acquired curvatures of the spine are not adequate for the correction or the prevention of scoliosis which results from congenital anomalies of the spine

2 Two cases are reported in which nearly all of each hemivertebra was successfully removed with marked correction of the spinal curvature

3 Since the deformity in these cases is usually progressive due to the more rapid growth of a number of the asymmetrically developed vertebrae fusion of the lateral halves of two or more of the vertebral bodies on the convex side of the curvature to check the rate of longitudinal growth would appear to be a rational and justifiable procedure

4 The fusion of the vertebral bodies rather than laminae in the treatment of certain cases of other types of scoliosis in growing children has been suggested

5 Final judgment of the efficacy of the procedure described cannot be given until many years have elapsed

Operation As now practiced, the operation consists of the removal of 3 to 4 inches of the proximal portion of each of 5 to 8 ribs on the convex side of the curvature i e those segments of the ribs which are mainly involved in the backward projection and angulation of the chest. It is a relatively simple partial subperiosteal resection of the ribs, and 5 to 8 ribs can be operated at one session There is a moderate amount of bleeding from the cut subcutaneous tissue and muscles, but the bleeding vessels are *small and easily seen and the bleeding is readily controlled Shock is rare* The one danger which can usually be avoided, is puncturing the pleura. If the pleura is punctured, the hole should be closed immediately with some muscle tissue the only result of the misadventure is some embarrassment of respiration not serious and entirely temporary I have seen no permanent damage from such accidental puncture of the pleura.

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In the case reported by Hyndman (47), there was marked rotation and angulation of the cord After incising the dura Hyndman decided to ease the angulation by creating more room for the cord and transplanting it. Accordingly " portions of the pedicles and transverse processes of the vertebrae and heads of the ribs at the fourth dorsal to the seventh dorsal

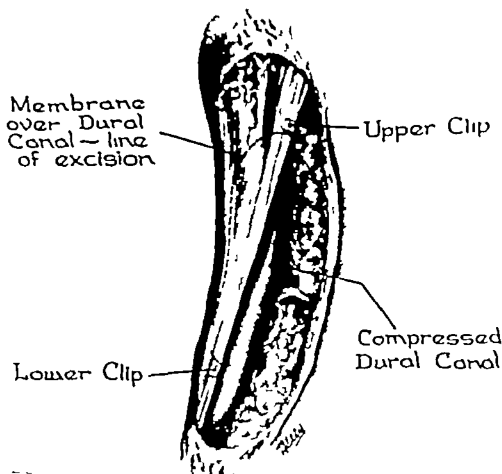


FIG 161 Excision of extradural band causing paraplegia in scoliosis (60)

inclusive were rongeured away on the concaved side (Fig 162) Four pairs of nerve roots were ligated and severed extradurally from the third to the sixth dorsal inclusive As soon as the roots were severed the cord with very little aid assumed its new position so as to relieve the acute angulation The patient rapidly recovered and two years later reported a continued state of well being

Hyndman called attention to the fact that a laminectomy alone would not have been adequate mobilization and transplantation of the cord were imperative for relief

The results of the venture to correct scoliosis by removing a hemivertebra or part of a wedge vertebra are not encouraging The operation is an extensive one technically difficult attended by hemorrhage and shock, and complicated by an anteroposterior vertebral deformity For the present therefore this operation is not being used Since not even the surgeons who have attempted the operation are inclined to continue using this procedure one must accept the fact that the operation at least as performed is not satisfactory This does not preclude the possibility however that perhaps in some modified form the direct surgical attack on the wedge vertebrae manifestly the ideal procedure theoretically will one day be successful

Fasciotomy Myotomy Capsulotomy

As was noted earlier in scoliosis there may be contractures of the soft tissues In fact Steindler speaks of structural scoliosis as a *contracture deformity* Of the accessible contractures, those in the muscles and fascia of the back and the pelvifemoral areas in fixed pelvic obliquity can be advantageously released by direct sectioning as an aid to forcible correction of the curvature In fixed pelvic obliquity with contracture of the abductors of the hip the fascia and muscles between the iliac crest and the femur must either be released from the iliac crest or cut across at some lower level This procedure often has to be combined with cutting of the iliotibial band through a cross cut or a Z plastic cut, and with release of the capsule of the hip joint. All the tissues must be cut and retracted until the thigh is in complete extension and in the neutral position and the abduction and flexion have disappeared. In the back, transverse section of the sacrospinalis muscle and the lumbar fascia at several different levels can be performed as an aid to subsequent forcible correction.

Both the fasciotomy and myotomy are easily done during a spine-fusion operation but the value of these procedures is yet to be proved

Laminectomy for Spinal Cord Compression in Scoliosis

The ideal treatment for a paraplegia complicating a scoliosis is to open the dura liberally at the apex of the curve and thus relieve the pressure on the cord or when the pressure is caused by a bony spur or by an extradural band (Fig 161) to remove the cause of pressure McKenzie and Dewar (69) who collected and reviewed 41 cases, concluded that early laminectomy is advisable and that it should not be delayed too long They based their conclusion on the following facts (*1*) In skilled hands, decompression of the cord is not a dangerous procedure (*2*) There is often constricting pressure due to a tight dura a congenital band or a bony spur (*3*) Continued compression of the cord may result in irreversible change and permanent loss of function.

changes in the epiphyseal plates If, then, this retardation could be applied unilaterally to the vertebrae on the convex side of the curve, the growth of the vertebral bodies on the concave side would be relatively accelerated, the bodies of the vertebrae in the major curve would become structurally more nearly normal, and the curvature would be partly or entirely corrected Theoretically, the prospects from such an operation seem good

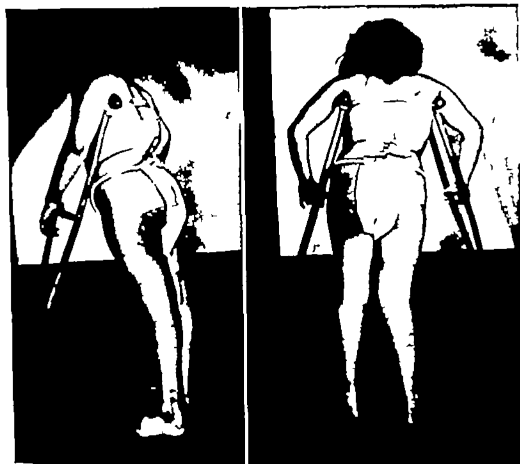


Fig 163 Photographs of patient after laminectomy she is now able to walk with crutches

In the past the dorsal vertebrae were considered inaccessible However at present the dorsal vertebrae are readily and safely reached through an intrathoracic transpleural approach. The author has used this method in experimental surgery on dogs since December 1949 seeking to produce a scoliosis through multivertebral epiphyseodeses in which the so-called epiphyseal plates and the neighboring epiphyseal cartilages were thoroughly scarified unilaterally So far a scoliosis in the dorsal area has not developed Epiphyseodesis in the lumbar area was actually applied to 4 children by Dr Le Mesurier of Canada (personally related to the author

In Love and Erb s (61) 2 patients, in whom a bony ridge was present in the neural canal anteriorly and caused compression of the spinal cord, removal of the bony ridge allowed anterior transplantation and liberation of the spinal cord The operation on their second case that of a 17 year old boy involved a left costotransversectomy and section of the fourth and sixth nerve roots of the left side because they were tense and tugged on the cord

In a recent case of mine, that of a 12 year-old girl, gradual improvement followed a laminectomy (Fig 163)

The lesson to be learned from the known 45 cases of structural scoliosis

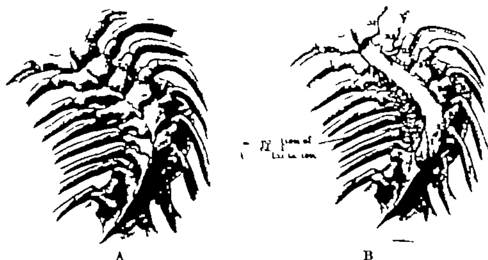


Fig 162 Operative transplantation of spinal cord for paraplegia complicating scoliosis (47) A, Showing the degree of scoliosis maximum angulation at the sixth dorsal B Illustrating how cord was transplanted

complicated by paraplegia is that early operation, before irreversible damage has occurred in the cord, is imperative Conservative treatment has nothing to recommend it and delay is dangerous. The operation must relieve pressure on the cord whether that comes from the dura alone, some adventitious band a bony spur or sharp angulation of the spine The so-called transplantation of the cord anteriorly or laterally has much to recommend it since adequate room is thus provided for normal functioning of the cord Particular attention must be paid to releasing, by sectioning whatever nerve roots seem to be taut and pulling on the dura.

Unilateral Vertebral Epiphyseodesis

This procedure has been contemplated as a curative measure ever since it was used experimentally to produce a scoliosis. Its rationale is based on the finding that growth of a vertebral body can be influenced and retarded by

transpleural approach the bodies of the dorsal vertebrae from the seventh to the twelfth inclusive were stapled on the convex side of the curve The operation was performed on November 25 1949 which now becomes a memorable date in the history and progress of orthopaedic surgery The authors noted that "The patient's postoperative course was uneventful and she returned to school after the second postoperative week So far the result has not been extraordinary The authors note Roentgenograms taken four months post-operatively show no change in the degree of curvature nor in the position of the staples But the time is too short for a definitive change What is more important is that a new therapeutic avenue has been opened in the management of structural scoliosis The future will assess its usefulness

The present stimulus to stapling the wedge vertebrae in structural scoliosis is infectious and I have no doubt that many operations with numerous technical improvements will be performed

Pleural Decortication for Thoracogenic Scoliosis

As was described in Chapter IV scoliosis of thoracogenic origin is very definitely a contracture deformity Whether the primary disease is a pyogenic empyema or tuberculous pulmonary lesion there is an inflammation of intrathoracic tissue especially pleural tissue which results in scarring diminished aeration malposition of the trunk and frequently a scoliosis which varies from a mild to a severe degree All too frequently the deformity becomes very severe and resistant to the ordinary orthopaedic therapeutic modalities Specific attention was directed to the value of prophylactic measures to prevent its development A much more positive program is presented in a current report on pleural decortication (50A) as a preventative of thoracogenic scoliosis and as one step in the program of reducing a severe thoracogenic scoliosis.

The essential feature emphasized *is that in thoracogenic scoliosis there* is a marked contraction and thickening of inflammatory tissue including the pleura on the concave side of the curve that is, there exists a fibrothorax The object of pleural decortication is to excise the scar on the concave side of the curve and thus release the lungs and ribs so that reduction of the deformity and improved thoracic function become possible

As is well known and as was previously emphasized there is a strong tendency in thoracogenic scoliosis for the deformity to become severe Kergin and Dewar (50A) therefore advise that as soon as a scoliosis becomes apparent a pleural decortication should be performed as a preventive measure against further increase of deformity In the cases of mild scoliosis one need institute no treatment other than the pleural decortication and corrective exercises. In the severe cases the authors advise pleural de-

at the meeting of the American Orthopaedic Association in May, 1950) He did a unilateral lumbar epiphyseodesis in 4 children between the ages of 3 and 5 years. In a follow-up period of 6 to 10 years there has been no correction of the scoliosis Dr Le Mesurier's experience was with very young children Perhaps in an older group the operation might be successful. Certain it is that the dorsal vertebral bodies previously considered to be inaccessible can now be easily and safely exposed

Unilateral Vertebral Body Stapling

As was described in Chapter V on etiology it is currently believed that disturbed vertebral body epiphyseal growth plays an important although not completely determined role in the production of structural scoliosis Experimentally scoliosis has been produced through unilateral stapling of several vertebrae Nachlas and Borden (71A) at the last meeting of the American Orthopaedic Association (1950) exhibited the spines of several dogs in which a mild scoliosis, but one with the essential characteristics of a rotary lateral curvature was produced by stapling of several lumbar vertebrae The staples were inserted through an incision in the back. The placement of the staples was carefully calculated so that no damage would be done to the nerve roots, and the prongs of the staples would enter the center of each vertebral body and not damage the epiphyseal cartilages. In this manner by compression the growth of the vertebrae was retarded on the side of the stapling and uninhibited on the opposite side The operated vertebrae became wedged deviated and rotated to the convex side and a scoliosis resulted In one dog in whom a scoliosis had been produced the affected vertebrae were stapled on the convex side of the curvature and the experimental scoliosis corrected

Dr John R Moore of Philadelphia told me (on October 27 1950) that he had used staples on six cases of scoliosis one was a congenital scoliosis in a child six years old the others were idiopathic scolioses in children between the ages of nine and eleven years He used seven or eight staples in each case and imbedded them in the transverse processes on the convex side of the curvature All cases had mild single curves. They had had preoperative correction in plaster-of Paris jackets were kept in bed for three weeks after operation and have since worn supportive celluloid corsets. The period of observation has been about one year In none of the cases has there been any reduction of the curvature

Direct stapling of the vertebral bodies through an intrathoracic approach (this might conveniently be called internal stapling) has actually been performed on a scoliotic child. Rieth Hopkins and Dunlap (73A) in the April, 1950 issue of the Southern Surgeon reported the case of an adolescent girl with an increasing right dorsolumbar scoliosis. Through an intrathoracic

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cortication as a prerequisite to mobilization of the spine and other thoracic tissues The decortication should be followed by the use of forcible correction to reduce the curvature and a spine fusion to assure maintenance of reduction of the scoliosis The authors in their case 3 show a splendid result from the above program in a very severe case of thoracogenic scoliosis The authors give us further encouragement in their statement "Experience with the cases described here and others indicates that it is possible to carry out a satisfactory decortication many years after the onset of the original pleuritis although the operation may be difficult '

Contemplation of the results of the modern treatment of structural scoliosis offers good reason for encouragement True no cases have as yet been cured But as a result of a program of health education and almost universal periodic physical examination of children scoliosis is recognized and treatment is begun at a much earlier age than formerly—often in the stage of incipiency Conservative treatment has been highly successful in the majority of patients preventing increase of deformity in some and reducing the deformity in many others, so that there are few patients today in whom the scoliosis advances to a really severe degree Spine fusions in specific cases have helped to retain much of the improvement obtained by various conservative corrective measures. In the relatively small percentage of patients in whom severe angulation of the ribs occurs, a cosmetic rib resection improves the appearance of the back Of even greater importance is the fact that surgical ventures, already initiated offer the strong hope that the moment is not far distant when we may confidently anticipate a *surgical cure* of at least some types of structural scoliosis.

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